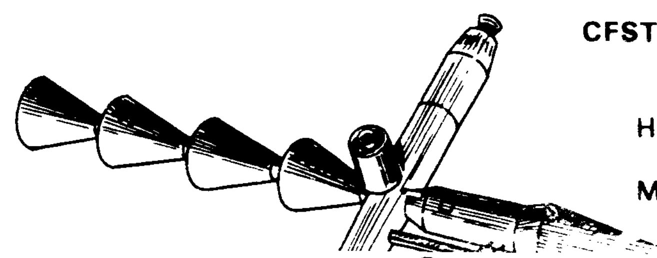
ORBITAL LAUNCH FACILITY STUDY

CONTRACT NO. NAS 8-11355

D2-82559-2 VOLUME II - A

OLF STUDY
TECHNICAL REPORT



PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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D2-82559-2

OLF STUDY TECHNICAL REPORT

FINAL REPORT

Volume II A

October 1965

Contract NAS 8-11355
Marshall Space Flight Center
National Aeronautics and Space Administration

~~The Boeing Company~~
Aerospace Division
Seattle, Washington

“[redacted]”

This document is Volume IIA, OLF Study Technical Report (Sections 1 through 4), of the final technical report of the Orbiting Launch Facility (OLF) study conducted by The Boeing Company for the Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Alabama, under Contract NAS 8-11355. The study was conducted under the technical supervision of Mr. William T. Carey, Jr.

The final technical report consists of four volumes:

Volume I:	OLF Study Technical Report Summary
Volume IIA:	OLF Study Technical Report (Sections 1 through 4)
Volume IIB:	OLF Study Technical Report (Sections 5 through 7)
Volume III:	OLF Study Research and Technology Implications Report

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VOLUME II A

1.0 INTRODUCTION

This document is The Boeing Company's technical report on the Orbital Launch Facility (OLF) Study. This study was performed under Contract NAS 8-11355 for the National Aeronautics and Space Administration as part of the Marshall Space Flight Center's (MSFC) overall investigation of orbital launch operations (OLO). This report covers the design and operational studies of orbital launch facilities, primarily for support of manned planetary missions. An OLF may be defined as an orbiting space station that is specifically designed to serve as a base for orbital operations--such as assembly, fueling, maintenance, checkout, and launch--in support of a manned planetary or lunar mission vehicle. Companion studies were awarded to Lockheed Missiles and Space Company of Sunnyvale, California for the Space Checkout and Launch Equipment (SCALE) study for design and operational requirements analysis of orbital checkout and launch equipment, and to the Ling-Temco-Vought Company of Dallas, Texas for the Advanced Orbital Launch Operations (AOLO) study. The latter study determined the operational modes and restraints for the overall orbital launch operations and integrated and evaluated the results of the three studies. Many of the requirements, therefore, upon which the Boeing OLF study was based were obtained from the associated contractors. For example, the Lockheed checkout equipment is installed aboard the OLF, and Ling-Temco-Vought provided the system modes as well as the integrated OLO equipment and personnel requirements for the OLF. This exchange of information required that the associated contractors maintain very close coordination during the entire course of the study.

The major OLF study objectives were:

1) Produce a conceptual design of an initial OLF to support a manned Mars flyby mission.

2) Specify the activities that dictate gravitational design criteria and evaluate the need for artificial gravity in OLF operations.

3) Identify the supporting research and technology problems associated with the development of the initial OLF and specify the R&D tasks required to solve these problems.

4) Establish ORL experiments necessary in the development of the OLF.

5) Determine the feasibility and design effects on the OLF of conducting scientific research and experiments on board the OLF.

6) Develop sufficient design details and cost data to allow feasibility of the OLF to be established.

7) Develop OLF concepts to support advanced manned planetary missions.

By NASA direction, the major effort of the study was devoted to the initial OLF for support of an early manned Mars/Venus flyby mission, with only a very small effort concerned with advanced OLF concepts. The mission vehicle supported by the initial OLF is a concept developed by MSFC and is fully described in Reference 1

To accomplish the study objectives, a plan was formulated in which specific jobs or tasks were outlined. These tasks, listed below, are grouped into several major study areas.

DESIGN STUDIES	Parametric Conceptual Design Studies Initial OLF Development Advanced OLF Evolution
OPERATIONAL STUDIES	OLF Operations and Systems Analysis Crew Requirements Service Maintenance and Repair Analysis Spares and Expendables Requirements Logistics Requirements
TECHNICAL STUDIES	Communications, Tracking and Data Management Checkout and Fault Isolation OLF Subsystems
SPECIAL STUDIES	Definition of ORL Experiments R&D Scientific Experiments Gravitational Level Analysis
PROGRAMMING STUDIES	RDT&E Program State of the Art

Design studies were iterative in nature and required design criteria inputs from other tasks, such as the operational and technical studies, as well as inputs from the associated SCALE and AOLO studies. The design studies received the greatest total effort of any study area. Operational studies have considered both preflight and flight operations during routine OLF operations and OLF operations required during orbital launch. Since the preflight operations have a minor effect on the overall OLF design, the study concentrated on the flight operations. These include Earth launch, assembly and checkout of the OLF, OLF operations in support of the orbital launch vehicle (OLV), and OLF operations after the orbital launch. Technical studies included the development of a system for management of all data involved in the total integrated orbital launch operations, determination of an OLF checkout and fault-isolation system, and selection of all on-board systems for the OLF. Also conducted were trade studies for optimum selection of on-board systems, where system choices existed.

Several special studies were conducted during the study. One--definition of orbital research laboratory (ORL) experiments required in the development of the OLF--included only experiments that could not be effectively conducted in Earth-based facilities. Another was the study of the use of the OLF as an orbital research laboratory to conduct scientific experiments between orbital launch operations. The types of experiments which would be conducted and OLF requirements to accomplish these experiments were investigated. A third special study, a gravitational level analysis, investigated the need or desirability for artificial gravity aboard the OLF. The need from an operational standpoint rather than from the crew psycho-physiological requirements was emphasized.

As a final step, a complete integrated RDT&E program plan was developed and the implications of the state of the art on the development of the OLF investigated. The integrated RDT&E program plan, which evaluated the costs and defined the design, development, manufacturing, research, and test programs necessary to produce the OLF, time phased those programs to allow the planned operational schedule to be met.

2.0 SUMMARY

The OLF study was performed as one part of a three-part study package of orbital launch operations under the joint sponsorship of MSFC and KSC. The other two were the Advanced Orbital Launch Operations (AOLO) and the Space Checkout and Launch Equipment (SCALE) studies. Boeing's prime responsibility was to provide data about Orbital Launch Facility (OLF) design that included its development and testing and the operational requirements of the OLF proper for integrating into the Advanced Orbital Launch Operations study prepared for NASA by the Ling-Temco-Vought Company. The following summary of this effort is organized to parallel organization of the main body of the study for easier reader correlation.

The major objective of the study was to produce a conceptual design of an initial OLF capable of supporting a manned Mars or Venus flyby mission. Concurrently it was necessary to perform OLF operational and technical studies to determine their design effects. Operational studies included: (1) Determination of postlaunch assembly and checkout operations and routine operations of the OLF, (2) Preparation of a maintenance analysis, (3) Preparation of a time-line analyses to determine crew size, (4) Determination of spares and expendables, and (5) Preparation of a logistic plan to supply the OLF and rotate the crew. Technical studies involved selection and definition of on-board systems such as electrical power and environmental control. In these areas, trade studies were made to allow optimum systems to be selected.

A second study objective was to specify the activities that dictate gravitational design criteria and determine OLF gravity requirements. The need for artificial gravity was oriented toward maintenance activities and routine operations rather than crew psychophysiological reasons. Although a design ground rule of the initial OLF was the use of centrifuges as the primary method of crew conditioning, alternate artificial gravity capability was an added design requirement.

A third objective was determination of the ORL experiments necessary to develop the OLF. This involved reviewing the various NASA, Air Force, and industry studies to determine experiments already suggested that were applicable to the development of the OLF and adding to these other experiments required to develop the OLF. They were selected to include only those which could not be effectively accomplished in ground-based test facilities.

A fourth objective was to identify the supporting research and technology problems associated with the development of the OLF and to define the R&D tasks required to solve these problems. This required development of a complete integrated research, development, test, and engineering (RDT&E) plan, including funding.

Other major study objectives were: (1) Sufficient development in detail of the OLF design to provide substantiating data for an estimate of the feasibility of the OLF mode of OLO operations, (2) To develop OLF concepts for advanced missions support, and (3) To determine the feasibility of conducting scientific research and experiments on board the OLF.

To accomplish the study objectives, a program plan was prepared that essentially divided the job into four general areas of activity: (1) The design phase, which included the parametric study, design of the initial OLF, definition of subsystems, and OLF evolution; (2) Technical and special studies; (3) Operational studies; and (4) Programming studies, including determination of ORL experiments necessary in the development of the OLF. Initially, a parametric design study was made to develop a baseline concept. Inputs to this study were obtained from AOLO and SCALE studies as well as other NASA and early Boeing OLF studies. From the baseline concept evolved the initial OLF shown in Figure 2.0-1. Figure 2.0-2 shows the program plan and summarizes the tasks defined to accomplish the study objectives and their relationship to each other and to other NASA studies.

Major design criteria and study ground rules were:

1) The OLF will be designed for a 5-year operational lifetime, with a 0.99 probability of no meteoroid penetration.

2) The OLF will accommodate a full-time crew of 12 and 18 crewmen for periods of 15 days.

3) The OLF will provide a 7 psia (shirtsleeve) environment within the living and working quarters and between MORLs.

4) The OLV and tankers will be hard docked to the OLF during orbital launch operations, except during the final countdown and launch of the OLV.

5) The OLF will be capable of providing artificial gravity backup.

6) Nominal time in space for crewmen is 180 days, which dictates a requirement to rotate half the crew every 90 days.

7) Initial launch will provide sufficient spares and expendables to maintain the OLF and crew for a period of 135 days.

8) Sufficient spares will be stocked to ensure a probability of 0.99 that the spare will be available when required.

9) A Saturn V will be used for initial launch of the OLF.

10) The logistic spacecraft will be a six-man Apollo with a payload of 5440 kg (12,000 lbs.).

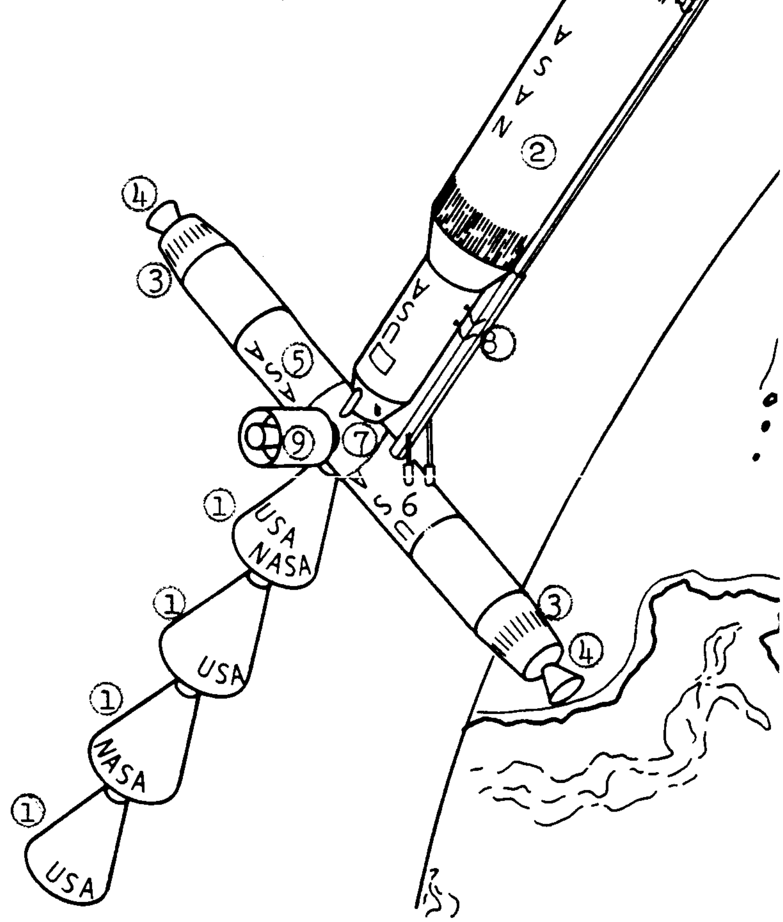
2.1 Principal Results

The studies outlined in the study plan are briefly described and their results discussed below.

2.1.1 Operational Studies. - These studies define operational activities of the OLF, starting with OLF operations and continuing through maintenance, crew requirements, spares and expendables, and logistics.

2.1.1.1 **OLF Operations.** - OLF operations consists of two distinct phases. The first, the orbital assembly and checkout phase, takes place immediately after

Orbit Altitude - 535 km (289 N. Mi)
Mass - Approx. 85,000 kg. (190,000 lb_m)
OLF Length - Approx. 54 m (177')
OLF Diameter - Approx. 7.5 m (23')



1. Lox Tanker
2. Orbital Launch Vehicle (OLV)
3. Manned Orbital Research Lab. (MORL)
4. Apollo Logistic Spacecraft Command Module
5. Experiment Bay
6. Hangar Bay
7. Hub
8. Umbilical Tower
9. Apollo Service Module

Figure 2.0-1 OLF MODE - ORBITAL LAUNCH OPERATIONS

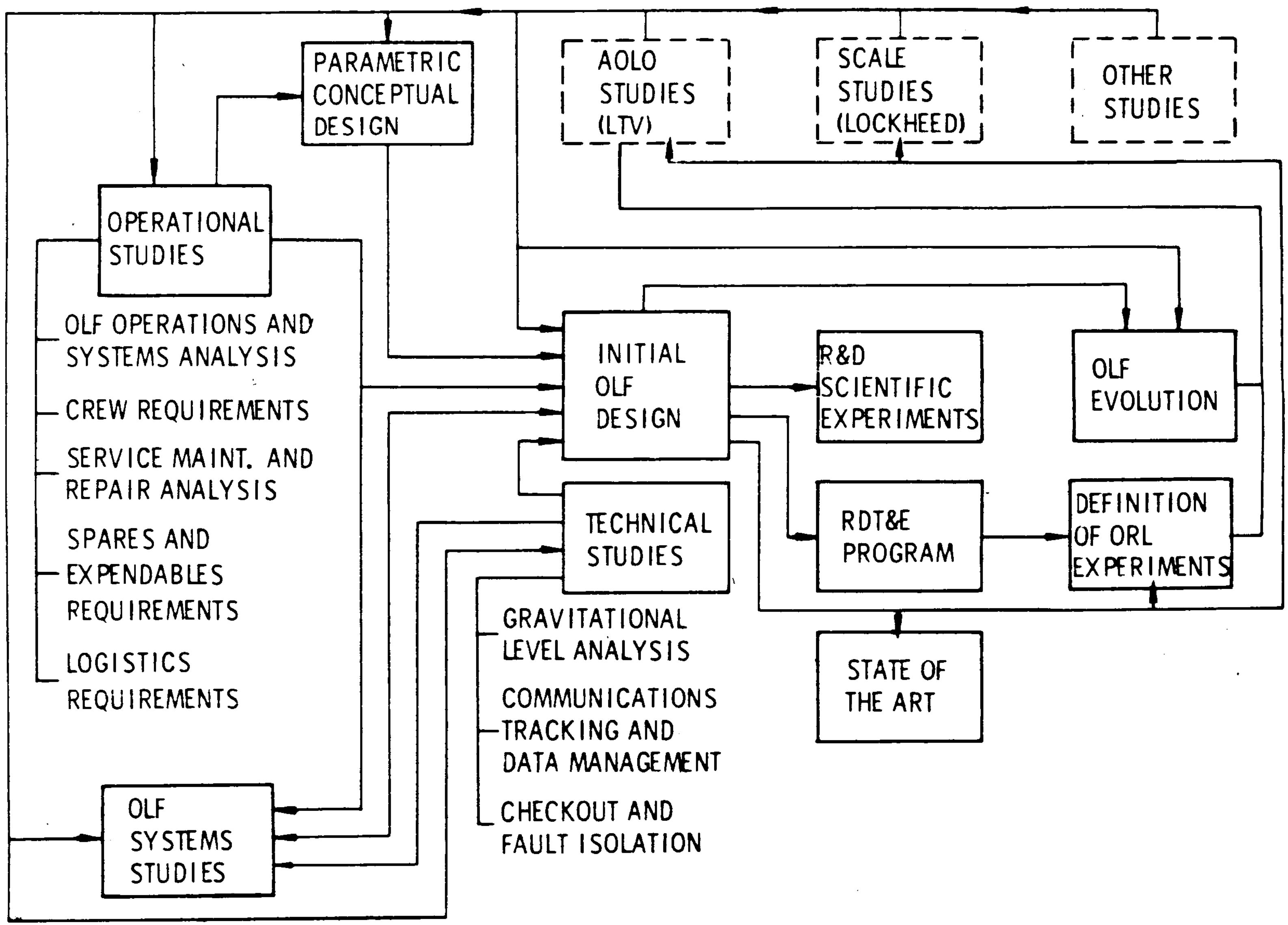


Figure 2.0-2 OLF PROGRAM PLAN

launch when the OLF has achieved a 185-km (100-n.mi.) mile orbit. At this point the S-II stage is separated and the OLF is injected into a 535-km (289-n.mi.) circularized orbit. Once this has been achieved the assembly and checkout functions commence, beginning with the separation of the Apollo command module and its docking to one of the MORLs. The crew enters the MORL and progressively activates all of the OLF subsystems until the OLF is fully checked out and operational. This phase takes about 55 hours from Earth launch and requires a crew of five.

Following verification of the OLF's operational status, the second phase, routine operations, begins. This phase consists of:

1) Station operations which include subsystems monitoring, navigation and orbital maneuvers, logistic operation, and housekeeping activities.

2) Personnel operations such as crew conditioning, crew training, personal care, relaxation, nutrition, and sleep.

3) Maintenance operations. (These are defined later in this summary.)

A function and task analysis of station and personnel operations established that maintenance and operation of the OLF required a minimum crew of four. This analysis assumed crew requirements for duties only connected with operation of the OLF proper. Duties such as conduct of scientific experiments and orbital launch operations were excluded.

2.1.1.2 Maintenance Plan. - The OLF maintenance plan, which provides the overall concept under which maintenance activities are conducted, also served as a framework for the determination of maintenance equipment and spares. A maintenance analysis of OLF proper systems was performed to identify the maintenance requirements; this data was then integrated with other OLO systems data developed independently by Ling-Temco-Vought and Lockheed. The basic OLF maintenance concept emphasized fault correction, by replacement of components, with a minimum of other repair being performed in orbit. This concept is based on the assumption that the checkout equipment is generally capable of isolating fault to a replaceable-component level with a minimum of additional maintenance equipment.

Both scheduled and unscheduled maintenance of the OLF proper were investigated, as well as the integrated OLO maintenance activities conducted on the OLF involving, in addition to the OLF proper, the checkout equipment, logistic spacecraft, and orbital support equipment. The hours required in these activities are summarized as follows:

Maintenance Function	OLF Proper Only	Total Integrated Activities
Life Support/Environmental Control . .	2.41	2.77
Electrical/Electronics . . .	0.50	1.41
Structures/Mechanical . . .	0.58	0.84
Total	3.49	5.02

2.1.1.3 Crew Requirements. - The objective was to determine how many personnel and which skills were required to assemble and ready the OLF for orbital launch operations, sustain it during OLO and conduct routine OLF operations. Detailed crew activities and task time requirements were determined and the necessary skills for performing the various tasks identified in the operation and in the maintenance portion of this study and consolidated under crew requirements. For each task, manpower, skills, and time estimates were made that considered only the work anticipated and the number of people required. Only secondary consideration was given to crew utilization and scheduling. A time-line analysis of the functions that considered time for rest, nutrition, and personal hygiene, was the basis for a realistic schedule of crew activities. This analysis did not consider scientific experiments while in orbit.

It was estimated that the total effort required for assembly and checkout operations be 106 manhours. For a five-man crew, allowing some contingency for scheduling, the elapsed time required for this phase of the operation, using a "normal" schedule was between 2 and 3 days. However, for this brief a period of time, it was felt the crew could utilize a high activity schedule to accomplish the work in as short a time as possible. This was accomplished by reducing relaxation time by 0.5 hours and sleep by 1.0 hours, resulting in an assembly and checkout operation lasting about 55 hours with a crew of five.

For the OLF routine operations, it was determined that a minimum crew of four was required. Figure 4.3-5 shows a manpower utilization curve that clearly indicates that four men are the optimum crew, leaving the least unscheduled time per man. Additional crewmen would decrease the workload on each individual man only slightly because personnel operations such as sleep, relaxation, and nutrition take up a major portion of a man's time.

2.1.1.4 Spares and Expendables. - Spares include those replaceable components stored in the OLF to maintain it, the checkout and launch equipment, the orbital launch vehicle, the LOX tankers, the logistic spacecraft, and the orbital support equipment (OSE). Expendables are those consumables subject to resupply that are either consumed directly, such as food or propellants, or that are eventually consumed or rendered unusable by wear and tear.

The extended length of the OLF mission established the necessity for continuous maintenance and logistic support to ensure a high probability of mission success. The previously described maintenance analysis was used as a basis for determining the OLF proper system spares, reliability, and mass. An initial spares loading was established that insured a 0.99 probability of having the correct spare when needed. The spares provisioning was optimized through use of a computer program technique that incrementally determined the maximum increase in probability of having the correct spare available at the least increase in mass. The mass of spares for each major item is shown below:

OLF	1155 kg (2546 lbs.)
Checkout Equipment	68 kg (150 lbs.)
Logistic Spacecraft	247 kg (545 lbs.)

OSE	199 kg (438 lbs.)
OLV	1433 kg (3160 lbs.)
Tankers	415 kg (915 lbs.)
Total	3517 kg 7754 lbs.

The OLF spares resupply requirements, determined through use of the computer program previously described, resulted in the following 90-day resupply requirements for the integrated systems:

Average	140 kg (309 lbs.)
Minimum	40 kg (88.5 lbs.)
Maximum	403 kg (889 lbs.)

To support the OLF proper, its crew, and OLO, certain supplies and expendables must be provided and regularly resupplied. These may be divided into (1) OLF proper expendables and (2) mission-dependent expendables required to support OLO. Expendables required to support the OLF proper and its crew of four for 90 days are shown below.

Life Support Expendables (nitrogen, oxygen, food, ECS, etc.)	1195 kg (2640 lbs.)
Propellants (non-spin mode) (orbit keeping, OSE, etc.)	391 kg (865 lbs.)
Propellants (for alternate spin mode)	1090 kg (2400)
Crew Support (personal equipment and miscellaneous)	67 kg (153 lbs.)

2.1.1.5 Logistics. - The primary objective of the logistics task was to define the provisions, equipment and spares required on board the OLF at initial launch, and to define the resupply expendable requirements in a form applicable to the different phases of orbital missions. In preparing the logistic plan, it was assumed that the launch of the OLF with a Saturn V provides the capability of placing in orbit sufficient spares and expendables to maintain the OLF for 135 days, and that every 90 days a six-man Apollo logistic vehicle would be launched with replacement supplies and personnel. A logistic plan was prepared for each of the following operational concepts:

(1) Initial OLF logistic support

(2) Alternate logistic support, including initial orbital qualification tests

(3) Post-OLO logistic support

The first concept assumes that the OLF and associated equipment have been adequately tested on Earth and that the orbital launch operation commences with the placing of the OLF in orbit and ends with the departure of the flyby mission vehicle, the OLV. Figure 4.5-1 shows the logistic support that occurs during OLO, commencing with the OLF launch at day zero and culminating with the orbital launch at plus 170 days. During this period the OLV spacecraft, two logistic spacecraft, four LOX tankers, and an S-II stage containing liquid hydrogen, are launched. A summary of the logistic support in terms of mass follows:

OLV propellants	420,000 kg (927,000 lbs.)
OLV Mass	113,000 kg (249,000 lbs.)
OLF supplies and expendables, including those required to support the OLV.	18,000 kg (40,000 lbs.)
Total	551,000 kg (1,216,000 lbs.)

In addition a total of 13 men will have been orbited, of which 3 are OLV mission crew.

The second concept or plan that includes the initial test and proving period allows for qualification tests of the OLF and orbital operations prior to the start of OLO. The first phase commences with day-zero launch of the OLF, which is run through qualification tests, and is followed by phase two, which commences at plus 60 days. During this phase an OLO qualification test program is conducted during which a practice OLV and tanker are launched and rendezvoused. The last phase, the mission orbital launch operation, commences with the ground launch of the OLV spacecraft at plus 390 days, and ends with orbital launch at plus 530 days. During these phases, six logistic spacecraft will have been launched, two OLV's, five LOX tankers, and two S-II stages containing liquid hydrogen. In addition, a total of 30 men will have been orbited during this period. A brief summary of the logistic support in terms of mass follows:

OLV propellants	508,000 kg (1,121,000 lbs.)
OLV mass	226,000 kg (498,000 lbs.)
OLF supplies and expendables, including those to support OLV's.	30,000 kg (67,000 lbs.)
Total	764,000 kg (1,686,000 lbs.)

The last concept studied, the Post-OLO logistic support, calculated the resupply mass for OLF routine operation as 2050 kg (4505 lbs.) every 90 days with a crew of four.

2.1.2 Design Integration. - The major effort of the study design of the initial OLF involved considerable detail study. It was necessary to define design objectives, perform a parametric study to evolve a baseline concept, and from this evolve the initial OLF through design iteration exercises. The initial OLF used two MORL modules, as building blocks joined by an interconnecting cylindrical structure. The MORl modules were used with minimum changes to configuration and subsystem design. A secondary task, using the initial OLF as a starting point, was development of the advanced OLF to support the more sophisticated manned Mars-landing and lunar-ferry missions.

The baseline design criteria selection was made primarily through an evaluation of 12 parametric configuration designs. The parametric designs were conceptual in nature and reflected only major configuration parameters such as size, shape, and external features. Three basic concepts were developed, each meeting the selected baseline design criteria. The first configuration, using existing or planned concepts to the maximum extent possible, required four Saturn 1-B's to launch into orbit. This required orbital rendezvous, docking, and assembly of the component parts. The second concept used two MORL modules with an interconnecting cylindrical structure that served as a docking hub, hangar bay, and experiment bay. At launch the MORLs were retracted into the cylinder and the entire OLF was launched with a single Saturn V. The last concept modified the second concept by dividing it into separate payload packages, allowing it to be launched by three or more Saturn I-B's. After evaluation, the second concept was selected and became known as the baseline design concept.

2.1.2.1 Initial OLF. - The initial OLF, developed from the baseline concept selected above. (Figure 5.3-1 of Section 5, Volume II B shows the initial OLF.) The initial OLF consists of two MORL modules connected by a primary cylinder 7.14m (23.4 ft.) in diameter and approximately 28.6 m (94 ft.) long, of a corrugated semi-monocoque aluminum structure, with three aluminum shields for meteoroid protection. For launch the MORL modules are retracted into the cylinder and a crew of five rides atop the launch configuration in a six-man Apollo. In this configuration the payload is about 38.5 m (126 ft.) long. As part of the OLF studies, the maximum airload conditions during boost were found to exceed the structural capability of the current S-II design; therefore, structural modifications may have to be made to the S-II or launch restrictions imposed. At launch, the lift off mass of the OLF is 67,230 kg (148,215 lbs.) including approximately 14,000 kg (31,000 lbs.) of spares and expendable supplies.

Extended for orbital operations, the OLF measures 54 m (177 ft.) long. This length is established primarily by the requirement for a back-up artificial gravity capability. At 4 rpm, the living quarters and operational facilities located in the MORL's have an artificial gravity level of approximately 0.37 g. The MORL's are maintained with an atmospheric pressure of 7 psia. The interior configuration of the MORL modules remains essentially unchanged except that the crew living quarters have been moved from the inboard compartment to that just outboard of the centrifuges, and the inboard ones now house the checkout equipment on one MORL and a maintenance shop on the other. Located in the center of the cylinder is a hub containing a docking station with docking ports for the OLV, LOX tankers, and logistic spacecraft, and a terminal section to which the elevator tubes connect and in which airlocks provide access to the OLV, experiment bay, and exterior of the OLF. The terminal section and elevator tubes, maintained at a pressure of

7 psia, provide a shirtsleeve environment for travel between MORL modules. Between the hub and MORL are an experiment bay on one side and a hangar bay on the other, each having a volume of about $425 m^3$ (15,000 $ft.^3$)

For maintenance and operation of the OLF and certain orbital launch operations, a number of mechanical items of equipment were required. Some of these such as Apollo docking and handling mechanisms, airlocks, and docking ports were used with minimum modifications from other systems. There were, however, certain mechanisms peculiar to the OLF such as (1) The MORL module extension system, which locks the MORL in a retracted position for launch and permits the remote extension of the MORLs by pressurization of the bays to 0.5 psia; (2) The umbilical service tower, which transfers LOX from the tankers to the S-II stage of the OLV, transfers other fluids and gases to the OLV, and provides electrical connection between the OLF and OLV; (3) the elevator system designed to carry personnel and supplies from either MORL to the hub and through a pressurized route from one MORL to the other; (4) A 4.07m (160 in.) hangar door capable of being retracted within the OLF cylinder and controlled from the docking hub and (5) A handling mechanism to place the Apollo in the hangar bay for maintenance.

2.1.2.2 OLF Subsystems. - Basic objectives established for the OLF subsystem studies included; (1) Use of the MORL subsystems to the maximum extent feasible, (2) Recognition of the problems associated with providing a maintenance capability for manned space vehicles in a space environment through simplification of service and maintenance procedures and efficient use of spare parts; (3) minimum extravehicular activities, and (4) recognition of the special considerations that must be given to providing redundant facilities and capabilities for a high probability of crew survival in the event of an emergency situation.

Based on these objectives, the general characteristics of each of the major subsystems on board the OLF were determined as described below.

Electric Power System. - The routine operational phase subsequent to assembly and checkout will require an average power capability of approximately 10.0 kW, with a peak load of 11.5 kW. Based on the average power requirements, 50% is AC(115/200) volts $\pm$ 2%, 3 phase, 400 cps; 25% is regulated DC(28.0 $\pm$ 0.5 volts); and 25% is unregulated DC(24-31 volts). A study was conducted to evaluate solar-cell/battery and Isotope/Brayton cycle power subsystems that would be compatible with the OLF configuration. Primary emphasis was placed on the weight comparison between the two systems.

Included within the weight parameter for the solar-cell/battery configuration, are the penalties for control-moment gyros of 930 kg (2050 lbs.) and reaction-control propellant of 580 kg (1285 lbs.) per year necessary to orient and maintain stabilization required for Sun orientation. Since solar energy is being generated only during part of the orbit, batteries must supply power during dark-side operation. Station operation during the shadowed portion of the orbit require 6.96 kWh of electrical energy delivered to the useful busses as derived from the electrical load profiles. Assuming a 0.8 regulator efficiency, 7.6 kWh is required at the battery outlet. Then assuming a 0.7 battery efficiency, 10.8 kWh must be delivered to the battery for charging during the Sun-side operation. Other energy requirements during Sun-side operation are computed to be 12.8 kWh. Assuming the same efficiency as above, 14.05 kWh of energy must be delivered to the unregulated bus with an average power requirement at the bus during one complete orbital cycle of 22.8 kW. For 5 years and 10%-solar-panel decay assumed per year, the initial solar-panel power output would have to be 38.5 kW. The total weight of the solar-panel system for 5 years, including penalties imposed by the Sun-orientation requirement and propellant consumption and batteries during dark side operation, was 5926 kg (13,070 lbs.).

The Isotope/Brayton cycle system, as described in the MORL documentation, provides 11 kW of power and was readily adaptable to the OLF installation. Primary weight adjustments were made for relocation of the isotop heat source from the MORL skirt to the OLF hub, which required the addition of 1,665 lbs. for OLF electrical-distribution-system equipment and an adjustment in the radiation shielding mass. Total weight of the Isotope/Brayton power system for a 5 year life span was 3433 kg (7570 lbs.).

Based primarily on the assumed availability of the Isotope/Brayton cycle with the MORL system and its potential advantages associated with a long OLF mission life, this system is currently recommended for the OLF.

Guidance and Navigation. - The basic requirements of the OLF guidance and navigation system are very similar to those required for the MORL vehicle. These include automatic and manual orbital determination and correction, rate signals for attitude stabilization, and periodic gyro drift corrections. Required in addition are an emergency rendezvous and docking control, in case of a guidance and navigation system failure in the docking vehicle, and an autonomous navigation capability to support the OLV launchings and provide backup navigation in case of a communication failure.

The design of the MORL system allows automatic orbital corrections to be made, based on ground tracking, orbital computations, and subsequent Earth-based commands. An alternate backup mode permits manual insertion of corrective maneuvers, based on data derived from the on-board guidance and display systems.

For modes requiring precise attitude hold, periodic correction of the inertial rate integrating gyros (IRIGs) is necessary because they have a random drift rate.

Emergency rendezvous and docking control uses a radar interrogator aboard the OLF and a transponder in the docking vehicle. The radar supplies range, range-rate, elevation, and azimuth indications to the guidance computer. Calculations are then made and the velocity increments displayed for the required rendezvous.

An autonomous navigation backup system requires the addition of an inertial measuring unit, sextant and scanning telescope, and the horizon scanner feeding the digital computer. Computed orbital parameters are displayed and manual operation of the orbit-keeping thrusters then corrects the orbit.

Attitude Control & Stabilization. - The attitude control and stabilization system provides vernier orbit-injection control, based on Earth commands automatically inserted into the control system, to maintain attitude corrections during the OLV assembly and checkout, tanker fuel transfer, preignition separation, orbital maneuvering capability, and station-keeping capability for correction of orbital decay. The long-term mission life requires station-keeping maneuvers during logistics resupply, scientific experimentation, and artificial gravity operation. Both automatic and manual control are required during all operations.

Use of an Isotope/Brayton Cycle electric-power unit eliminates the requirement for continuous orientation of the OLF along the Sun line. Random orientation, with attitude control only for docking or orbit keeping, appears feasible for the OLF and allows periods of up to 30 days without use of the reaction control system.

Adequate stabilization and control performance for the OLF can be achieved, using the MORL control system modified to delete the control moment gyros, relocate the reaction control and orbit keeping jets, and change the control logic. An injection stage is used for orbit injection. Selected reaction control jets of the various vehicles docked to the OLF, will be controlled by the OLF stabilization and control system during OLO build-up, to provide good control authority of the relatively large disturbance torques.

Environmental Control/Life Support System. - The requirements for the OLF environmental control/life support (EC/LS) system vary from that for two MORL modules. Instead of a requirement to support 12 men continuously or 18 men for 15 days, the OLF must support only 4 men during routine operations or up to 13 men briefly during OLO. This more modest requirement is balanced to some extent, however, by the much greater volume to be environmentally controlled and the increased contamination introduced by outgassing of the much greater interior surface area of the OLF.

The environment of the hangar and experiment bays, the three hub compartments, and the elevator tubes will be maintained by the two MORL systems with minor modifications. Systems that will require modification are the air-distribution system and possibly the atmospheric contamination removal equipment. The latter will have to be reexamined since personnel loading during normal OLF operations has been reduced but the increased area of structure and OLF equipment will increase the contamination through outgassing, vaporization of lubricants, etc. It is expected that a balance may be achieved, however, without gross modification of the MORL systems.

Common ducting with appropriate valving is used between the two MORLs and the hub for final pressurization and control of the atmosphere of the hub compartments and elevator tubes. Following initial pressurization to 3.5 psi, the hub elevator terminal and elevator tubes will be fully pressurized and maintained at 7.0 psi for shirtsleeve commuting between MORL modules and the hub. When it is found necessary to fully pressurize either the experiment or the hangar bay, one bay will be evacuated to provide pressurization for the other. Atmospheric conditions of each compartment will be checked and monitored prior to and during their use to determine hazardous conditions of contamination, temperature, and pressure. Circulation and temperature-control units are provided for each compartment. Umbilical life support connections, provided in each compartment of the OLF, use the MORLs for atmospheric supply and purification. The MORL environmental control system concept, utilizing the Tapco-Bosch CO_2 reduction system providing for oxygen regeneration, will be used because of its long-term economical advantages.

Crew Support. - The crew support provisions will be similar to that for the MORL and will include personal equipment, food handling and preparation, recreational facilities, hygiene provisions, and other miscellaneous items required for crew comfort and OLF habitability. Clothing and similar equipment is divided between that carried with each crewman and that stored on board the OLF itself at launch. Sufficient accommodations and provisions are provided on the OLF for temporary crew overloads of up to 18 men for 15 days in emergencies.

Checkout and Monitoring. - The checkout requirements are based on a detailed evaluation of each major subsystem. The OLF checkout and monitor system reflects maximum use of the space checkout-and-launch-equipment-system concept developed by Lockheed to implement the equipment requirements for the OLF. A detailed review of the checkout system, as described in the Lockheed final report, clearly indicates that the functional capabilities and flexibility inherent in this system can be used to satisfy most of the OLF checkout and monitoring requirements. The OLF data requirements will not impose any design changes on the space checkout-system configuration.

The major interface requirements with the checkout system will be associated with software programming. The integration of the checkout program with the OLF program will require careful considerations with respect to timing for data access, evaluation, display, recording, and formatting for retransmission.

Data Management and Communication. - The basic elements of the orbital launch complex are the OLF, the OLV, and the Earth-based mission control center. Secondary elements integrated into the communication subsystem are propellant tankers, supply vehicles, and extravehicular astronauts. The three major elements require full duplex voice, televisioned, and data transmission; the secondary elements require a somewhat lesser capability.

Three channels will be required, (1) a narrow-band data channel will be used exclusively for bioastronautical and environmental monitoring that is associated with the health and welfare of the astronauts, (2) a wide band data channel capable of handling computer program inputs and high speed readout of stored data, and (3) a non-real-time, slow-scan-system, narrow-band TV channel that can transmit commercial-TV-quality pictures in real time at a frame rate of 30 per second.

Ground Network Characteristics. - The orbital parameters of altitude, eccentricity, and inclination impose a number of constraints on the communications subsystem. The altitude of the OLF will determine (1) the length of time that line-of-sight communication can be maintained with each ground station, and (2) the maximum range over which the communication links must operate. To provide economic and reliable operation, the communications subsystem should be capable of working into established ground stations with operationally proven equipment. At the same time, care must be exercised to prevent saturating the ground facilities that will be used to provide support for the ever-increasing number of short-term operations. The cost of providing 24-hour-per-day manning of multiple, remotely located ground stations for the life time of an OLF makes it mandatory to optimize the number and location of these stations. Although the cost of keeping a tracking ship continuously on station may be extremely high, it may be feasible in conjunction with other simultaneously occurring orbital programs.

For analysis purposes, the ground track was made of the OLF's circular orbit of 289 nautical miles altitude and inclination of 30°. Assuming that reliable communications can be provided only for elevation angles of greater than 5° (which corresponds to a communication radius of 1200 nautical miles), 36 land - and ship-based ground stations will be required to provide nearly continuous coverage; while one-per-orbit contact can be accomplished, using only three ground stations. Three stations located in the western hemisphere (Corpus Christi, Texas; Quito, Equador; and Antofagasta, Chile) will provide reliable, once-per-orbit communications at nearly the same time in each orbit. (See Figure 5.4-73 in Section 5 of Volume IIB.) A total of 127.4 minutes per day of communication time is available, with a minimum time for any orbit being 5.1 minutes. Wide-band, microwave transmission facilities exist between Corpus Christi and the Manned Spaceflight Center (MSC) in Houston. Full duplex, 60-words-per-minute-teletype radio circuits, using the Canal Zone as a relay point, are available between Quito and Antofagasta and Washington, D.C. It is expected that these are, or will be tied directly into MSC. Buffering and format conversion would be required to transmit video data received at these stations to the MCC.

At present, the Quito and Antofagasta stations are not equipped to support a manned mission such as OLF. This deficiency must be corrected by 1975 because of the utility that can be achieved by using these stations to support OLF.

2.1.2.3 Advanced OLF Concept. - The purpose of the advanced OLF studies was to define an OLF capable of supporting advanced missions such as manned Mars-landing and lunar ferry missions. The approach used was to assume the existance of an initial OLF in both cases but to independently develop two advanced OLFs by evolution of the initial OLF--one to support the manned Mars-landing vehicle and the other to support the lunar ferry.

A basic difference in mode established for support of the advanced concepts, was that the tankers and OLV would not be docked to the OLF during orbital operations. This eliminated the need for the umbilical service tower and associated fluid storage tanks as well as for the OLV and tanker docking ports and mechanisms. Since direct contact will not exist between OLF and OLV, personnel and equipment must be moved between these vehicles by orbital support equipment.

Mars Landing Mission OLF. - In reviewing changes required in the initial OLF to support the manned Mars-landing mission, it became apparent that no major design changes were required. In fact, elimination of the service tower and OLV and tanker docking ports allowed by the new docking mode made possible additional changes that further simplified the basic concept.

The advanced OLF is 3.05 m (10 ft.) shorter than the initial OLF in the launch configuration. (See Figure 5.5-2, Section 5, Volume IIB). However the overall length of 54 m (177') in the deployed configuration dictated by the artificial gravity requirement was maintained. In the new configuration, the elevator tube telescopes for launch and in the deployed condition provides continuous passage from one MORL to the other. Access to the hub is through a normally open hatch, the tubes and hub being maintained at 7 psia. In this configuration it was possible to reduce mass 5,870 kg (12,936 lbs.) under the initial OLF mass.

Reusable Lunar Ferry. - A review of the criteria for the lunar ferry mission showed that it was well within the initial OLF capability and in most cases less demanding than that for the Mars-landing mission. Two new requirements were introduced by the use of a reusable nuclear engine aboard the lunar ferry OLV. The first requirement--an orbital support assembly vehicle (OSAV) as part of the OSE--introduced a need for a new mechanism to stow the OSAV in the hangar for maintenance. No particular problem was foreseen in meeting this new requirement. The second requirement was for an engine cold flow test facility at the OLF to test lunar ferry replacement engines. Although a design exercise was not conducted on this new problem no particular difficulties are foreseen as ample room is available and test-data management could easily be handled by checkout equipment already aboard the OLF.

Composite Design. - While the approach to the advanced OLF study did not consider a composite design, the results certainly suggest the feasibility of this. The initial OLF with minor modifications can accommodate all the requirements for the advanced OLF, including space for the OSAV and engine-cold flow test facility required by the lunar ferry OLF. The main advantage of an advanced OLF design lies in the simplification possible due to elimination of the umbilical and OLV and tanker docking ports; however, the advantages of the composite design may outweigh the advantage of a separate advanced OLF design. First, the composite design is feasible. Second, the developmental problems and costs of one design, although slightly more complex, should be less than for two separate designs even where the second one is an evolution of the first. Third, there should be a good possibility that a single OLF may be designed and built with a sufficiently long life span to support the complete spectrum of missions from early planetary flybys to manned Mars landing.

2.1.3 Special Studies

2.1.3.1 Gravitational Level Analysis. - The purpose of the gravitational-level analysis was to determine the requirement for artificial gravity on the OLF. The approach taken was to analyze all the activities to be performed in the initial OLF to determine gravity restrictions, if any, imposed by each activity. Gravity requirements from a biomedical standpoint were not considered in this analysis, as the phychophysiological responses to prolonged unrestrained weightlessness are a subject of other studies. The effect on personnel is therefore considered only from the point of view of performing functions, such as maintenance, movement of supplies, independent of the effect of zero gravity on man himself. The requirements for artificial gravity were also considered, from the standpoint of its effect on equipment.

In assessing man's performance in zero gravity, it was necessary to use research data provided by tests in which simulators were used, such as air bearing platforms which allow determination of man's moment of inertia about several axis, and neutral buoyancy tanks which indicate the effect of weightlessness on gross motor performance and equipment handling. As scant information is available regarding man's weightless performance in an actual zero-gravity environment, the analysis was largely based on Earth experiments.

Personal Propulsion. - Gross bodily movement from one point to another is facilitated tremendously by the absence of gravity, and should present no problems in moving short distances. For longer distances, handholds must be provided for continuous directional correction. Initial inaccuracies in "jumping off", which are of little consequence in confined quarters, will on long traverses result in missing the landing point or body attitude by large amounts. A guide rope, handholds, or an astronaut maneuvering unit will be required. It should be noted that during artificial gravity modes extravehicular activities will at best be hazardous because centrifugal force will tend to separate an astronaut from the OLF.

Application of Forces. - In Boeing tests on simulated weightlessness, it was found impossible to sustain any force while nearly frictionless. However, if there is no requirement for a continuous application of force, the situation is different. It was found that a high force could be momentarily applied before a reactance force overcame the body's inertia, and that reactance could then be absorbed slowly by a handhold. It was noted in experiments that the operator accepts with ease the need to hold on to prevent drift and absorb reactance and use a hand, arm, or leg to clamp onto the structure being worked on. For applying forces for any length of time, some sort of restraint was required unless the force were less than 22.5 newtons (5 lbs.), where a handhold or a toe hold, such as found on boats, would suffice. When properly tethered, the same forces may be applied as in a normal one-g environment.

As a result of the analysis, it was determined tha all personnel activities performed inside the OLF would be simplified or accomplished in a more nearly Earth-like manner with artificial gravity. In the case of nutrition the lack of gravity would require that all foods be supplied in a paste form. With gravity, food could be provided in more normal Earth-like forms. Some difficulties would be experienced in artificial gravity due to the Coriolis acceleration; however, in a preperly designed OLF these problems would soon be minimized as man learned to tolerate these effects. In the initial OLF certain activities would be seriously complicated by the rotation required for artificial gravity. For example, if the OLF were rotated during docking operations, the amount of propellant that would be required by the docking vehicle would be greatly increase; therefore, during docking acitivities and certain other operations the OLF rotation would have to be discontinued until these operations were completed. If artificial gravity could be maintained throughout the life of the OLF, then the need to provide tethering provisions for everything not built into the OLF would not be required; however, in the initial OLF, where artificial gravity is provided only on a part-time basis, complete tethering must be allowed for.

In analyzing the OLF systems it was established that in the majority of cases there was no definitive requirement for gravity because, by proper design, systems could operate in a weightless environment. In some cases, systems are penalized by artificial gravity; for example, the guidance and navigation system, would require that the inertial measuring unit, sextant and horizon scanner be mounted on a stable platform, and the attitude control and stabilization system would be more complex due to orbit-keeping maneuvers required while rotating.

The following table summarizes the findings of the study, which, generally speaking, disclose that artificial gravity is not mandatory from the point of view of human performance or on-board systems. The requirement for artificial gravity for experiments is entirely dependent on the experiment.

OLF ACTIVITIES	
Space Environment (Assembly, docking, maintenance, etc.)	Undesirable
Shirtsleeve Environment (Assembly, maintenance, housekeeping, etc.)	Desirable
OLF SYSTEMS	
Guidance and Navigation	Undesirable
Attitude Control and Stabilization	Undesirable
All Other Systems	Desirable
OLF EXPERIMENTS (68 INVESTIGATED)	
34 Zero-Gravity Effects Experiments (on bacteria, blood, germination, etc.)	Zero g required
22 Physical Knowledge Experiments (electrooptical, launch detection, etc.)	Desirable
12 Artificial-Gravity-Effects Experiments (Satellite retrieval, personnel and cargo experiment)	Gravity Required

Should zero gravity be permissible from a crew psychophysiological standpoint, it may be desirable to develop a zero-gravity concept. A preliminary configuration of such a concept was investigated during the study. A comparison of this design with the initial OLF indicated that a zero-gravity concept would be a mechanically simpler design, a shorter configuration, and cost less.

2.1.3.2 R&D Scientific Experiments. - Because for the majority of its 5-year operational life time, orbital launch operations will not be in process, the OLF during these inactive periods can be used as an orbital research laboratory. Moveover, even during orbital launch operations experiments could be conducted by proper scheduling. Therefore, a study was conducted to determine the R&D scientific experiments that could be performed on the OLF. As the range of experiments was so great, from biomedical to those associated with physical mechanical sciences, it was not feasible to investigate all possible experiments within the time limits of the study. For this reason, first priority was placed on experiments providing data of value to the advanced OLF concept. No attempt was made to schedule the experiments. A total of 97 experiments were considered, and it was established that it was feasible to perform 68 of these on the OLF, of which 22 are concerned with the orbital support assembly vehicle (OSAV) used on the advanced OLF. These by and large are limited to the maneuvering of the OSAV in a spinning and nonspinning environment, establishing its reserve or satellite retrieval capabilities, and other experiments that will establish whether the OSAV is capable of performing the tasks to which it was intended.

The design effects on the OLF of conducting experiments may be summarized as follows: (1) adequate space is available in the OLF for all experiments and for housing the personnel required to conduct the experiments, (2) electrical power is marginal now and would require added capability to be built in for many of the proposed experiments, (3) experimental equipment mounting provisions would have to be installed for many of the experiments and an OSAV handling mechanism would have to be added for experiments involving this piece of equipment, and (4) improved stability characteristics would need to be provided for the OLF for some experiments such as the manned orbital telescope.

2.1.3.3 Definitions of ORL (Orbital Research Laboratory) Experiments. - An important part of any development plan is the experimental research program which, to develop an OLF, involves both Earth-based and orbital experimentation. The high risks and costs of providing facilities for performing experiments in orbit provide an incentive for accomplishing much of the experimental research on Earth-based facilities. However, in many cases these will not provide the degree of confidence nor the environmental simulation required and these experiments must be performed in an ORL. The objective of this study was, therefore, to identify and describe experiments not being performed as part of other programs, but required to develop the OLF, that must be accomplished in orbit. The emphasis was on OLF operation rather than crew biological considerations.

The approach taken was to first review experiments being performed as part of other programs or studies to determine which of those already suggested were applicable to the development of the OLF. Then as the study progressed and the OLF design evolved, additional OLF-peculiar experiments were identified and described. Parallel effort on experiment identification was underway in the SCALE and AOLO studies, and as the experiment study progressed it became evident that in the overall orbital launch operations certain duplication of effort was occurring since the development of the checkout equipment and the OSE, and analysis of orbital operating techniques and procedures, revealed problems similar to those in the development of the OLF. To avoid this, under the direction of NASA, an experiment investigation committee was formed which selected the experiments that had been suggested by Boeing (OLF), Lockheed (SCALE) and LTV (AOLO) and assigned them to the appropriate contractor for detailed description of the experiments. The method used to establish OLO orbital experiment requirements over and above those being discussed for Gemini, Apollo, AES, and MORL was to review actual operational capabilities required to support an orbital launch of a manned vehicle, and to compare them with the anticipated capabilities evolving from pre-OLO orbital research programs currently postulated. Typical operations required to support an orbital launch using a permanent facility were categorized as:

1) Orbital transfer and rendezvous (OTR)
2) Docking (D)
3) Personnel transfer/artificial gravity (PT/AG)
4) Personnel transfer/zero gravity (PT/ZG)
5) Cargo transfer/artificial gravity (CT/ZG)

6) Cargo transfer/zero gravity (CT/ZG)

7) Erection and assembly (EA)

8) Maintenance and repair (MR)

9) Fluid/propellant transfer and storage (F/FTS)

10) Checkout (C/O)

11) Launch (L)

Following identification of the OLO orbital experimentation requirements and the assignment of experiment description responsibility, each experiment requirement was analyzed in sufficient depth to provide a reasonable basis for describing the experiment or series of experiments. Boeing, as part of this study, was given the responsibility for describing 21 experiments in terms of mass, volume, power, duration, etc. (Detailed descriptions of these are given in Paragraph 6.3 and the results summarized in Figure 6.3-7, Volume IIB).

2.1.4 OLF Development Program. - A preliminary integrated research development test and engineering (RDT&E) plan was developed for the initial OLF baseline concept. The plan determines and describes the design, development, research, test activities, and resources necessary to produce the OLF to support a 1975 interplanetary mission. In addition the plan also provides data for a basis of evaluating the permanent OLO mode, of which OLF is a part, with other modes of orbital launching. Approximately 4 years are required from hardware go-ahead to OLF launch, and approximately 9 years from subsequent engineering study contracts to OLO planetary mission applications.

This level of study, conceptual design, has not revealed any critical development problems. The reason is the OLF program plan is based on using MORL configurations and concepts and assumes the critical items in the MORL program have been resolved. The packing element of this initial RDT&E plan is Orbital Research Laboratory (ORL) experimentation. Four major spacecrafts are required to satisfy the requirements for development and operational deployment. The four spacecrafts provide a unit for structural and dynamic testing, a flight unit, a flight backup unit, and a proof test unit.

2.1.4.1 Design and Development. - The design phase of the OLF will evolve the definition of specifications and fabrication drawings for the facility, ground-support equipment, and operational requirements. The objective of the development phase will be to prove that the design does in fact comply with the requirements and specifications. The evolution of the system design and development will consist of these parts:

1) Fundamental Research -- In this part the objective is to perform operation analyses, mission definition, trade studies, simulations, and identify critical technical requirements.

2) Applied Research -- During this phase preliminary design and spacecraft design, including the spacecraft specification and vehicle integration effects, will be performed as will the ground and ORL experiments.

3) Development -- And, lastly, design requirements and layouts will be updated, procurement specifications will be prepared, the design verified, and production drawings and test requirements released.

Starting in January of 1966 fundamental research will have to be initiated and will last to the end of 1967. Concurrently, applied research will be started in the second quarter of 1967 and will continue to the second quarter of 1972. During the last two and a quarter years of the applied research phase, hardware development will be carried on concurrently, primarily for orbital support and procedures development.

2.1.4.2 Research Program. - A major objective in the conceptual design selection of the OLF was to use developed technology and hardware because that approach and the selected preassembled design minimizes research requirements. As a result, all the selected systems and techniques presently identified are within the state of the art, except for the ORL experiment requirements summarized previously. However, as progressive preliminary and detailed OLF design studies are performed, it is expected that OLF developement problems that require research will become more evident.

2.1.4.3 Manufacturing Plan. - This plan defines the tooling concept, fabrication and assembly flow, facilities and equipment requirements, manufacturing and quality control development and also provides a basis for costing. The plan provides for use of existing tooling, facilities, processing techniques, and manpower skills to the maximum practical extent. The plan is based on use of Saturn S-IC program facilities and tooling, with modifications, for the OLF.

2.1.4.4 System Qualification and Test Plan. - The approach taken in the test plan is in that MORL and Apollo will be operational prior to the OLF, the extensive use of their hardware in the OLF will provide space-qualified hardware without additional major orbital test programs,and that final acceptance of the OLF will be conducted in orbit on the operational vehicle prior to actual orbital operations. This means that the OLF will be launched into orbit prior to commencing the flyby mission to allow acceptance testing on the OLF proper and OLO operations. The acceptance testing of the OLF will take 60 days, followed by an OLO integrated systems test that will last 330 days. During the integrated testing, a nonmission OLV and tanker will be orbited and docked. Prior to the launch of the OLF, an extensive proof-testing program will be conducted. Five major compartmental areas (two MORLs, a hub, and two bays) will be assembled and tests conducted on a proof test vehicle to verify static and dynamic loadings, operation of mechanism and the development of safety, and operating and maintenance procedures. This will be followed by ambient ground testing of the complete vehicle that will include verification of electrical-power-load profile, heat-load profile, operational procedures, etc.

2.1.4.5 Logistics Plan. - Logistics encompasses the equipment, materials, and services required to operate and maintain the OLF during the life of the program. This includes: (1) crew training, which will require extensive use of academic training and simulator training, most of which will be carried out at existing NASA facilities with the assistance from OLF program contractors; (2) a spares support plan that will include the range of components to major assemblies required to support the OLF prior to launch; (3) the development of all technical data required for ground support of the OLF and flight crews.

2.1.4.6 Facilities and Support Equipment. - Facilities and support equipment requirements were evaluated and it was generally concluded that manufacturing capability for the OLF would be available either from NASA or private industry. Full and partial mission simulators will be provisioned at Houston and KSC and housed in a semiclean enclosed high-bay area. An adjacent low bay area will provide consoles, computer racks, etc. This facility will be a modification of the existing MORL mission simulation facility. A ground network system using a unified S band communication system for a once-per-orbit transmission will require such typical sites as Corpus Christi, Antofagasta, and Quito. At present only Corpus Christi is equipped to support the OLF and the other stations would have to be upgraded.

2.1.4.7 Funding Plan. - The objective of the OLF costing was to develop a program cost of sufficient quality and validity that could be used to establish a time-phased funding plan that allowed successful accomplishment of the initial OLF. The following table shows in terms of 1965 dollars the funding requirements:

Fiscal Year		Dollars in Millions
1966		0.5
1967		4.3
1968		20.3
1969		34.5
1970		117.5
1971		242.9
1972		217.0
1973		166.0
1974		58.2
	Total	861.2

Advanced OLF RDT&E Plan. - A preliminary advanced OLF RDT&E plan was developed to support the Mars landing in 1983 and start of the lunar ferry operations in the first quarter of 1980. The plans for these missions assume that the initial OLF program is being, or has been conducted. These two plans are costed independentally of each other, but both are dependent on an initial OLF capability.

Costs are shown below:

Mars Landing:	$148.0 Million Dollars
Lunar Ferry Mission:	$148.5 Million Dollars

2.2 Conclusions

The OLF study fulfilled the objectives of this study and provided valuable insight into the problems that will be encountered in the research, development, testing, design, operation, and maintenance of an orbital launch facility. The comparison of different modes of interplanetary launches and orbital support modes, of which the OLF is one, are compared in the Ling-Temco-Vought AOLO study. Some of the more important conclusions derived from this study are:

1) The recommended initial OLF design concept evolved from this study is considered to be a feasible facility design and a very effective instrument for the support of manned planetary missions. It appears to be well within the expected state of the art for the time period of the early 1970's.

2) The use of Apollo and MORL building blocks in the initial OLF concept significantly simplifies the RDT&E for the facility, which is estimated to require four years from hardware go-ahead to launch and will cost approximately 861 million dollars.

3) Recommended initial OLF concept offers tremendous growth potential and is adaptable for support of such advanced missions as the manned Mars landing and lunar ferry missions with only minor modifications.

4) Considerable advantage may be gained by integrating advanced missions support requirements into a composite OLF design as early as possible in the OLF development.

5) The use of the OLF for R&D scientific experiments during the non-OLO period of orbital operation appears feasible and very appealing. Distinct effort should be directed at more detailed definition of the associated OLF support requirements and early integration of these requirements into the OLF development.

6) An additional possibility of the OLF in the field of experiments is its use as a "mother" spacecraft for experiment modules. In this concept a multipurpose mission module (MMM), or equivalent, is prepared on Earth for a particular family of experiments and is orbited and docked to the OLF which then serves as a base of operations and quarters for the crew. The advantage of this would be that complete laboratories could be prepared on Earth, rather than modifying the OLF for each set of experiments while in orbit.

7) Although the gravitational level analysis of this study was far from conclusive, indications are that unless psychophysiological effects of extended weightlessness on man demand artificial gravity, a zero gravity facility appears more desirable.

8) In the investigation of the orbital experimentation that may be required in the development of the initial OLF, it was found that to achieve the 1975 target date for the initial OLF, all of the data available requirements fall within the predicted AES period prior to MORL. However, all of the experimental requirements defined thus far are within the capabilities currently assumed for the AES.

9) All of the ORL experiments defined in this study and scheduled in accordance with the initial OLF RDT&E plan require experiment development go-ahead within the 1966-1968 time period. Detailed ORL experiment definition and implementation planning should commence in 1966.

2.3 Recommendations for Future Activity

The following future activities are recommended based on the knowledge gained by the OLF study. While they are not all directly concerned specifically with OLF design and operation, they are concerned with OLO.

1) To reduce crew radiation dosage or the radiation shielding requirements, a further evaluation should be made of the present 535 km orbital altitude to determine whether a lower altitude and/or different orbit inclination is feasible.

2) Trade studies should be conducted to determine the optimum orbit altitude for the least propellant consumption, for the full 5 years of OLF life. (Drag coefficients vary from year to year.) Lowering the orbit altitude would increase orbit-keeping propellants slightly, but could result in a substantial decrease in boost propellants, thus increasing logistic payloads. This would also be related to Item 1 above.

3) During the study it was assumed that radiation was uniform. Point dosage must be studied in detail to determine the radiation shielding provided by the OLF structure and equipment.

4) A reevaluation of the launch intervals constraints due to lack of available launch umbilical towers (LUT) should be performed. The provisioning of additional LUTs would reduce the present 170-day OLO to a lesser period, shorten the time in space for men and equipment, and might result in an overall reduction in costs.

5) A more detailed look should be taken at zero "g" OLF concept development, particularly if crew psychophysiological requirements allow prolonged zero "g" operation.

6) Future studies should be made of the integration of the initial OLF with advanced OLF design concepts to result in a multipurpose OLF. In this connection it will also be necessary to perform further studies to review the best supply mode for combined orbital operations. That is, hard-docking should be compared with remote and possibly both modes retained as at present. Explosion and radiation hazards should be considered in these studies.

7) The effects of orbital precession on orbital launch operations should be completely analyzed. This should include considerations of inclination and altitude on precession rate, precession rates on launch windows and the related effect of orbital inclination on the launch opportunity.

8) The R&D experiments for OLF implementation study was limited to enumerating and describing those experiments that can be performed in the OLF. Further studies are required to define and schedule those experiments that can be conducted concurrently with the initial orbital launch operation.

9) Further detailed studies must be conducted on ORL experiments required in OLF and OLO development to ensure that they have been fully defined and have

been integrated into the national space program.

10) A ground-versus-orbit-testing philosophy must be developed in order to ensure a correct balance of testing.

11) The effect of the OLF configuration on the Earth launch vehicle must be analyzed in detail because the S-II stage of the Saturn V is structurally marginal in this application. Perhaps revised environmental launch restrictions could be considered in lieu of design changes.

12) Although numerous other study areas were revealed wherein more detailed or extended investigation is required, most of these areas will probably fall within the normal course of required study in the overall OLF development. Such areas include:

a) OLF emergency operations (evacuation, rescue, etc.)

b) Crew training -- verification of adequacy or inadequacy of ground training in simulators.

c) Aerodynamic loading effects of OLF-type payloads on Saturn V launch vehicles.

d) Various detailed design studies of OLF on-board mechanical systems, the basic MORL module extension system, elevator system, service umbilical tower, equipment and cargo handling mechanisms, etc.

More detailed discussions and recommendations regarding the research requirements of an OLF development are presented in the Research and Technology Implications Report, Volume III, of this final report of the OLF study.

3.0 STUDY APPROACH

The OLF study, which involved several rather diversified types of activity, was primarily concerned with conceptual design of the initial OLF. Also required were operational studies leading to the definition of routine OLF activities, as well as those required in support of OLO; determination of crew requirements; establishment of the spares and expendables necessary to support the OLF; and definition of a logistics plan. Technical studies, especially those involving the onboard systems such as environmental control and electrical power, had to be made. In addition, several special studies were made of OLF R&D scientific experiments, ORL experiments required in the development of the OLF, gravitational requirements, and the RDT&E plan necessary to develop the OLF. Finally, design of OLF's for the support of advanced missions was briefly investigated.

Boeing, together with the other two OLO package study contractors, formed a team to study orbital launch operations in support of manned planetary and lunar missions. Because many of the requirements for any individual study within the OLO package were predicted upon results derived from one of the other companion studies, it was necessary that the three contractors work together essentially as a team. Figure 3.0-1 shows the major elements of information interchanged between Boeing and the other two contractors, and the major responsibilities of the OLF study. The figure shows only that information affecting the OLF study; it does not show the interchanges of information required between the SCALE and AOLO studies.

Information required from the SCALE study included primarily the development of checkout and countdown procedures and equipment and specification of OLV maintenance activities aboard the OLF. Information provided by LTV from their AOLO study included integrated total OLO crew size, integrated total OLO spares and expendables, integrated total OLO tools, specification of orbital support equipment (OSE) requirements, and the integrated data management requirements.

The OLF study in turn provided OLF design concepts to both associated studies. In addition, information provided specifically to the AOLO study included determination of the OLF proper crew size, OLF proper spares and expendables, OLF proper tool requirements, OLF data management requirements, and an RDT&E plan for the OLF proper. By <u>OLF proper</u> is meant those OLF requirements during routine operations not associated with OLO.

With the information supplied by the associated OLO package contractors and by studies generated in house, the OLF study effort then was to (1) design an OLF to house checkout and launch equipment, spares for the entire mission, entire OLO crews, and maintenance equipment; (2) determine the data management system; (3) determine a logistics plan, and (4) establish a service and maintenance plan.

The foregoing relationship of responsibilities applied primarily to the initial OLF. For the limited advanced OLF studies accomplished in the OLF study, the entire integrated OLO requirements were supplied to Boeing by Ling-Tempco-Vought.

As can readily be seen, with the considerable crossfeed of information required by the associated studies, and with the broad spectrum of subjects covered by the OLF study, it was necessary that a comprehensive and complete study plan be prepared and followed to achieve successful completion of the OLF study objectives. The coordination problem was further complicated by the iterative process required to complete the various study tasks.

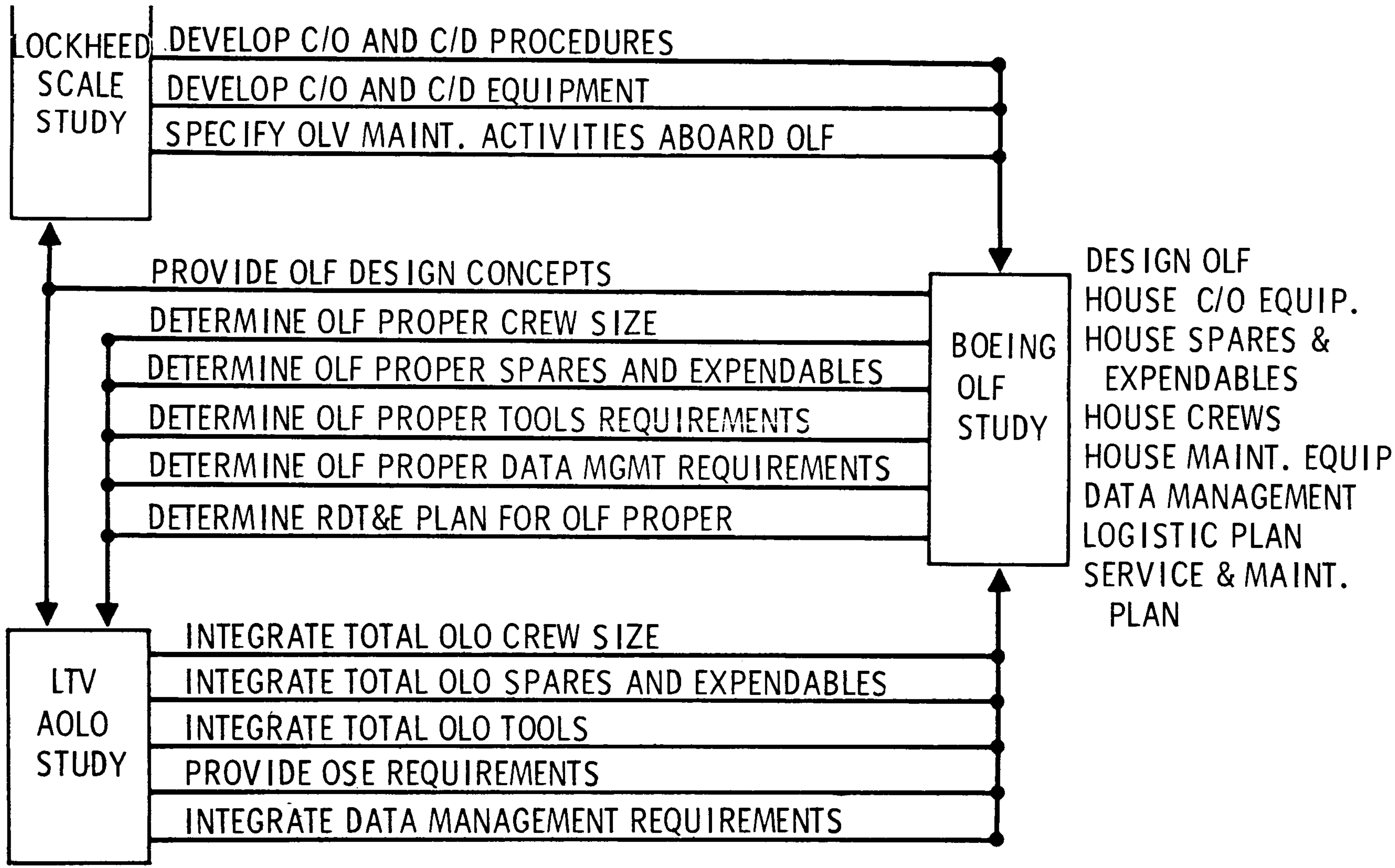


Figure 3.0-1 OLF INTERFACES WITH OLO PACKAGE

3.1 Study Plan

A detailed study plan was developed and documented in Boeing document D2-23638-1. To accomplish the major objectives outlined in Paragraphs 1.0 and 2.0, as well as those additional specific expected results outlined in the MSFC statement of work (Reference 2), the study was divided initially into the following 18 specific tasks and categorized into five major areas:

1) Design Studies
   - a) Parametric Conceptual Design Studies
   - b) Initial OLF Development
   - c) Advanced OLF Evolution
2) Operational Studies
   - a) OLF Operations and Systems Analysis
   - b) Crew Requirements
   - c) Service Maintenance and Repair Analysis
   - d) Spares and Expendables Requirements
   - e) Logistics Requirements
3) Technical Studies
   - a) Communications Tracking and Data Management
   - b) Checkout and Fault Isolation
   - c) OLF subsystems
4) Special Studies
   - a) Definition of ORL Experiments
   - b) R&D Scientific Experiments
   - c) Gravitational Level Analysis
   - d) Explosion Effects
5) Programming Studies
   - a) RDT&E Program
   - b) State of the Art
   - c) Program Manning Requirements

During the course of the study, MSFC cancelled the requirements for the explosion-effects study and the program-manning requirements; therefore, Boeing remained accountable for a total of 16 of these tasks. The manhours allocated to these tasks were directed towards intensifying the effort in defining ORL experiments.

In the detailed study plan, each task was carefully considered from the following standpoints:

1) Objective
2) Expected results
3) Guidelines and Assumptions
4) Approach
5) Alloted budget
6) Inputs and data sources
7) Outputs

In addition, a very detailed time-phased event network diagram was drawn showing the relationship to each other of the inputs and outputs of the various tasks and the associated OLO package studies. In this section of the report, however, a detailed discussion of the tasks will not be made, but the objectives of the 16 tasks completed during the study will be noted as follows:

1) Parametric Conceptual Design Studies -- To develop, through parametric analysis of major design variables, an initial OLF concept for detailed design iteration studies.

2) Initial OLF Development -- To develop the design for the recommended initial OLF (for the Mars or Venus flyby mission).

3) Advanced OLF Evolution -- To evolve a design evolution of the initial OLF (Task 2) into advanced concepts capable of conducting the more sophisticated planetary missions, including the manned Mars landing.

4) OLF Operations and Systems Analysis -- To provide the operations and systems analysis required for OLF systems synthesis and evaluation, and for integration of OLF activities with SCALE and AOLO study activities.

5) Crew Requirements -- To determine the personnel required to operate, maintain, service, and repair the OLF proper and to establish OLF design criteria, considering the total orbital personnel requirements.

6) Service Maintenance and Repair Analysis -- To establish basic service, maintenance, and repair criteria for OLF design considerations and to provide design effects of integrated OLF and OSE maintenance and repair activities for iterations and optimization of the initial OLF design.

7) Spares and Expendables Requirements -- To develop a spares philosophy and method of computing spares requirements and to determine the spares and expendables required to support the initial OLF proper.

8) Logistics Requirements -- To specify the total OLF logistics requirements of the OLF as a function of time, mission, and Earth launch vehicle payload capability and to integrate these requirements into a total logistics plan to sustain the overall orbital launch operations.

9) Gravitational Level Analysis -- To provide the basic criteria for determining the artificial-gravity requirements of the OLF as a function of orbital launch activities and types of OLV's to be launched and to apply these requirements to the initial OLF design.

10) Communications Tracking and Data Management -- To determine communications and tracking requirements for navigation and data management on initial OLF proper, to integrate all data management activities into a single data management plan, and to determine the effects on Earth-based facilities.

11) Checkout and Fault Isolation -- To determine the need for OLF on-board checkout and fault-isolation system, and to determine the effects on the initial OLF design of locating the checkout and countdown equipment on the OLF, the OLV, or between them.

12) OLF Subsystems -- To provide subsystem parametric and detail design information for initial and advanced OLF's and determine OLF design effects of subsystem variations.

13) Explosion Effects -- Task cancelled.

14) R&D Scientific Experiments -- To determine the feasibility of incorporating on the initial and advanced OLF, R&D scientific experiments such as scientific satellite repair, launching of probes, or other studies.

15) RDT&E Program -- To develop an RDT&E program plan for the OLF.

16) State of the Art -- Identify the present state of the art and the expected state of the art required to develop the initial OLF.

17) Program Manning Requirements -- Task cancelled.

18) Definition of ORL Experiments -- To identify and define ORL experiments required as part of the OLF development.

As mentioned before, the program plan includes a very detailed time-phased event network. This report presents a greatly simplified chart of the major study relationships as Figure 3.1-1. As will be noted, it is not time-phased, but does include consideration of related studies. It may be noted that Boeing activities are surrounded by a block drawn with solid lines; related studies are surrounded by a block drawn with dashed lines.

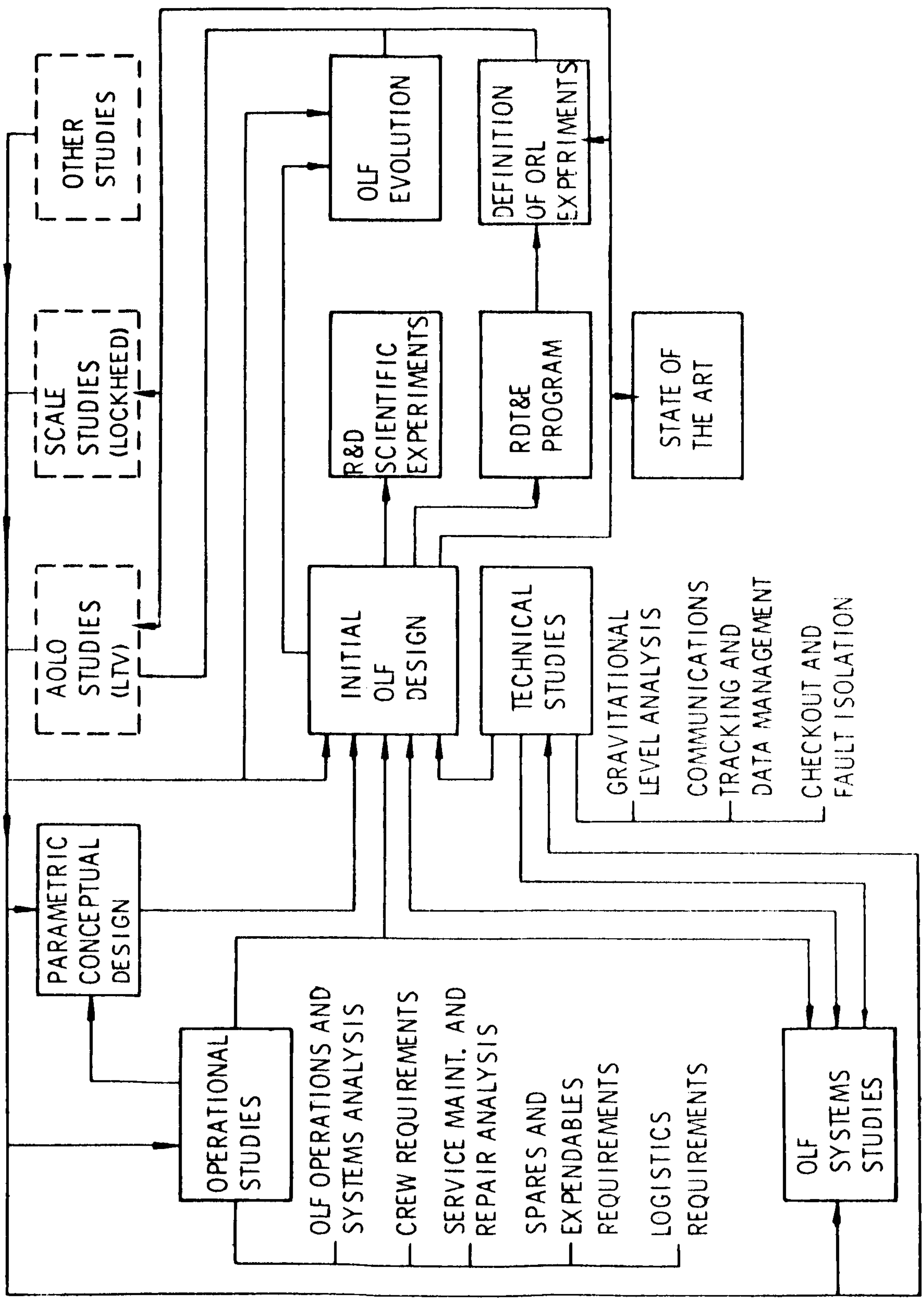


Figure 3.1-1 OLF STUDY PLAN

The figure shows the flow of information required to accomplish the various phases of the study. While it is realized that the study tasks are somewhat iterative in nature, the figure shows the major flow. For example, the initial study task involving the parametric conceptual design study shown on the figure required primary inputs from previous orbital launch operations studies by Ling-Tempco-Vought and by early Boeing operational studies. The parametric study in turn was a prime input to the initial OLF design.

In addition to the close observance of the study plan, another tool used to assist in the efficient conduct of the study was the holding of frequent coordination meetings among the three OLO package contractors and the NASA technical supervision from MSFC. Initially, when the study ground rules were being formulated and OLO operational modes being defined, it was necessary to hold these meetings as frequently as twice a month to obtain adequate coordination. As program planning became more firmly established, the need for the meetings diminished and they were held much less frequently.

3.2 Guidelines, Assumptions, and Ground Rules

Study ground rules and assumptions of a general nature observed in the conduct of the study were derived from the MSFC statement of work, coordination meeting decisions, and other sources. They are of a general nature and do not apply specifically to any special phase of the study as do the special ground rules applying specifically to design noted in Paragraph 5.0. The more important guidelines, assumptions, and ground rules of this study were:

1) Launch vehicles will be available in adequate quantities.

2) Launch vehicles used to launch and support the OLF will be the Saturn IB and Saturn V.

3) Launch vehicle performance and schedules will be made available by NASA.

4) Rendezvous and docking will be operational and reliable by 1970.

5) The AES and MORL will be available for OLF development and the MORL will be available for integration into OLF hardware in 1972.

6) The initial OLF will support chemical OLV's only.

7) Advanced OLF concepts will support either chemical or nuclear OLV's.

8) The initial OLF will hard dock to tankers and OLV for OLO.

9) The advanced OLF will accomplish OLO remote from the OLV.

10) Initial OLF design should if possible be evolved from an ORL concept.

11) Advanced OLF designs should if possible evolve from the initial OLF.

12) Initial OLF missions are the Mars/Venus flyby.

13) Initial OLF operational date objective is 1975.

14) Advanced OLF missions are the manned Mars-landing and lunar ferry.

15) Advanced OLF operational dates are 1980 for the lunar ferry mission and 1983 for the manned Mars landing.

16) Emergency escape capability from the OLF must be available at all times.

17) Information from other NASA studies will be used to the maximum extent possible.

18) Hardware concepts developed by other NASA studies, including on-board systems, will be used wherever effective on the OLF study.

19) Maximum advantage shall be taken of interchange of information with other contractors performing work on government contracts.

20) Design emphasis will be placed on those details peculiar to the OLF.

21) Practicable maintenance considerations will be employed in the OLF study.

22) Initial OLF lifetime will be 5 years.

23) Dimensionless parameters will be used to the largest extent possible. The international system of units (SI) will be used in addition to the English gravitational system in final presentations and reports.

4.0 OPERATIONAL STUDIES

A number of interrelated subjects have been grouped in this section. They are interrelated since to arrive at a logistic plan, it was necessary to determine the orbital operations crew requirements, and establish the spares and expendables necessary to support the OLF. Once these were defined, a logistic plan could be formulated.

The first of the operational studies was the OLF operations, which discusses in detail the tasks involved in the checkout and day-to-day operations of the OLF. This was followed by a maintenance analysis which established personnel tasks required to maintain the OLF and determined the required spares. In this connection, only the OLF subsystems for which Boeing was responsible were analyzed, spares and reliability data having been obtained through NASA for the other OLO systems. Using a Boeing computerized spares model, data from NASA and the Boeing maintenance analysis was fed into the computer to determine the optimum integrated OLO spares which would provide a probability of 99.9% that the spare was available when required. Once the operational and maintenance tasks were established, it was possible to define the crew necessary to operate and maintain the OLF in orbit. With crew size and functions established, it was then possible to determine the expendables required to service the OLF and support OLO crews. Finally, based on information evolved from the first four operational studies, a logistic plan for the support of OLO was prepared. This plan considers not only the logistics for supporting the OLF itself, but support requirements for OLO commencing with the initial launch of the OLF.

These studies were not performed in sequence, but in reality were an iterative process in which each study was constantly refined and updated as the result of the influence of one study on another; at the same time a constant updating was performed to reflect the latest information regarding all design integration studies. As a result, the operational studies, even though first in the final document, incorporate the intelligence achieved by all other OLF studies.

4.1 OLF OPERATIONS

Operational studies and accompanying systems analyses were fundamental parts of the OLF design study. It was necessary first to know what operations are expected of a facility to function in the intended environment; second, to know what operations are required of the facility to perform its designated role in the total operations; third, to identify systems functional requirements; and, finally to iterate these with respect to operational and design concept variations.

The approach considered most effective for accomplishing these tasks consisted of the following:

a. Definition of OLF mission objectives.

b. Formulation of preliminary operational and systems requirements, based upon the OLF mission objectives established above, and on information generated in previous space station and orbital launch operations studies. This provided the basis for initiating the conceptual design study.

c. Definition of major operational events required to meet the established objectives utilizing various design concepts.

d. Definition of tasks required to accomplish the prescribed major OLF events.

e. Function and task analysis to determine time, skills, numbers of personnel, systems, and equipment requirements.

f. Iteration and evaluation of the operational concepts and projection of systems requirements and design constraints.

g. Time phasing of OLF operations within the total OLO mission.

The following sections describe the OLF operational studies and systems analysis as performed within the framework of this approach.

4.1.1 Baseline Mode. - There are obviously many ways of performing an orbital launch operation. The particular mode of orbital launch operation selected by NASA and the associated OLO contractors for use as a baseline in this study is presented pictorially in Figure 4.1-1. The particular OLF configuration shown is the concept developed and recommended by this study for the Initial OLF.

The sequence of major events begins with the Earth launch and orbital injection of the OLF, with the subsequent assembly, activation and checkout of the OLF systems. Following verification of the OLF's operational status, the OLV spacecraft is launched from Earth, rendezvoused with the OLF, and docked to its special docking port in the OLF. The spacecraft is then checked out and, if found defective and non-reparable, another spacecraft is called for. After the operability of the spacecraft is confirmed, four LOX tankers are launched to

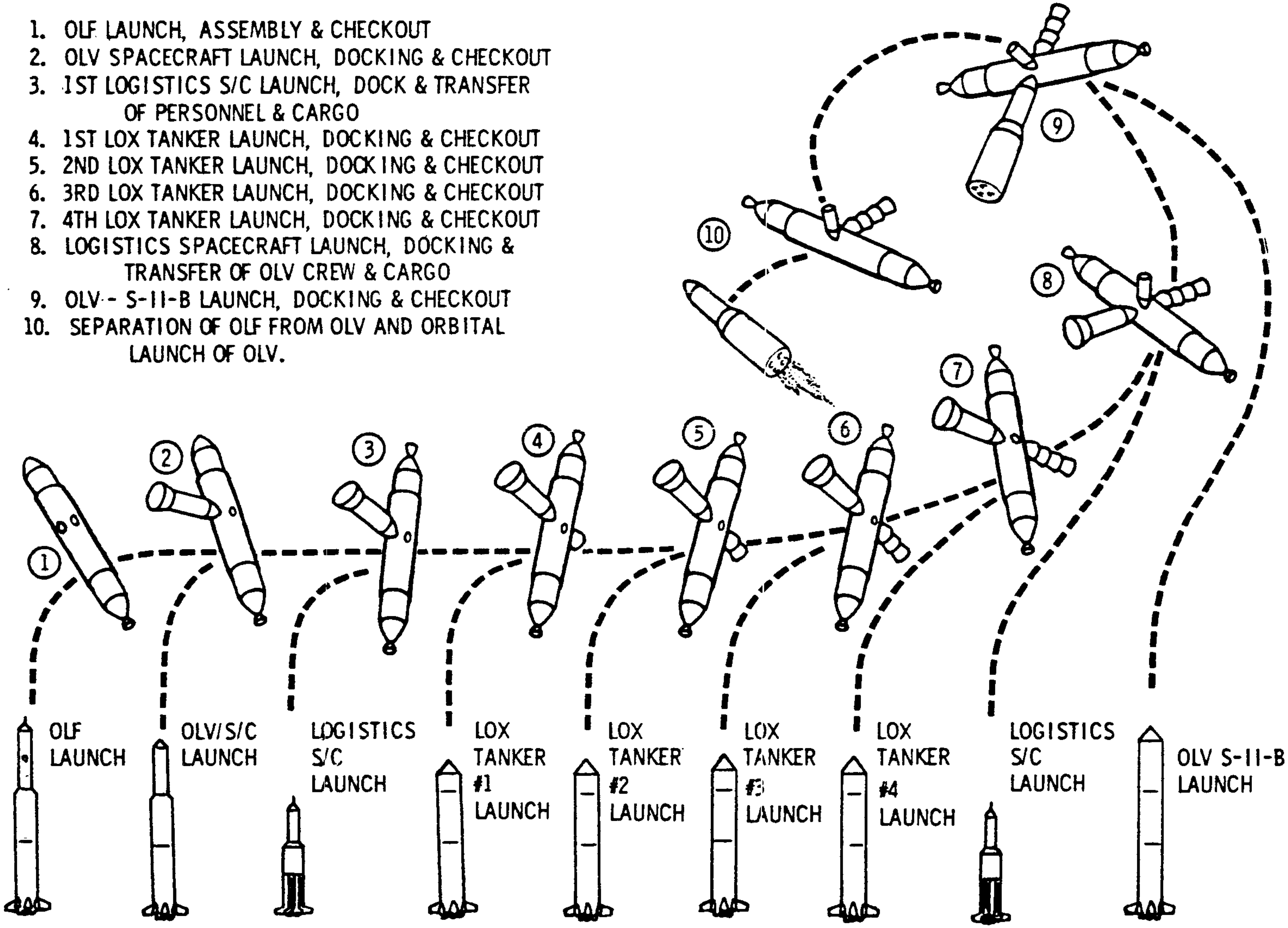


Figure 4.1-1 BASELINE MODE - ORBITAL LAUNCH OPERATIONS

provide the full complement of oxidizer for the OLV space booster (Saturn -IIB stage). These tankers are launched at intervals following the docking and checkout of the previous tanker with the first tanker arriving in orbit docking directly into the OLF docking port opposite the OLV spacecraft. Each subsequent tanker is docked into the aft end of the preceding tanker. As the OLV-Saturn-IIB stage was considered to be limited to 72 hours in orbit because of carrying its full requirement of liquid hydrogen, it is necessary to have the entire supply of liquid oxygen in orbit prior to the launch of the Saturn-IIB stage. The spacing of launches is governed primarily by Earth launch facility constraints. Just prior to the tanker orbiting operations, a logistics spacecraft with additional personnel and cargo is launched from Earth. Another logistics spacecraft is launched just prior to Saturn-IIB stage launching. This spacecraft delivers the OLV crew, other necessary personnel and cargo to the OLF. When all of the orbiting systems are in ready condition, the Saturn-IIB stage is launched, orbited and rendezvoused with the OLF. Following an inspection of the mating portion of the Saturn-IIB stage, it is mated with the OLV spacecraft and checked out. Liquid oxygen is transferred from the tankers to the Saturn-IIB stage through the umbilical servicing tower provided on the OLF. Following final checkout of the OLV with the OLV crew on board, the OLF is separated from the OLV and the OLV is launched into its interplanetary trajectory.

4.1.2 OLF Mission Objectives and Associated Study Guidelines

4.1.2.1 OLF Functions. - In a broad analysis of the overall orbital launch operations the OLF could, under various orbital launch situations, be expected to provide such functional capabilities as shown in Figure 4.1-2.

FIGURE 4.1-2 -- POSSIBLE OLF FUNCTIONS

1. Lodge the following:

    a. Station-keeping personnel
    b. Assembly, maintenance and repair, checkout and launch personnel
    c. OLV crew
    d. Scientific-R&D personnel

2. Hangar the following:

    a. Orbital Support Equipment (OSE)
    b. Orbital Launch Vehicle (OLV)
    c. Rescue & logistics spacecraft

3. Provide storage facility for:

    a. OLF spares and supplies
    b. OLV spares and supplies
    c. OSE spares and supplies
    d. Logistics spacecraft spares

4. Provide facility for:

    a. Rescue & logistics spacecraft docking

FIGURE 4.1-2 -- POSSIBLE OLF FUNCTIONS - Continued

b. OLV docking
c. OSE docking
d. OLF maintenance and repair
e. OLV & OSE maintenance and repair
f. Rescue & logistics spacecraft maintenance and repair
g. Servicing and propellant transfer
h. Scientific research and development activities
i. Monitoring and controlling (in varying degrees) OLF and OLV operations during assembly checkout, servicing (including propellant loading), countdown, and launch.

4.1.2.2 OLF Minimum Requirements. - Considering these possible OLF functions, the minimum OLF requirements were defined as follows:

- Provide orbital housing for OLO personnel, including the crews for OLF proper, checkout and maintenance crew, logistics and rescue spacecraft crews (if they are not part of the other crews mentioned), and any other special crews required for OSE operation. Housing of the OLV crew need not be considered a necessity in a minimum-type support facility except possibly in emergency.

- Provide the capability for at least monitoring and controlling the OLF and OLV through orbital checkout, servicing, countdown, and launch. for higher levels of OLF capability, assembly and maintenance and repair operations will require monitoring and control as well.

- Provide docking provisions for OSE, logistics spacecraft, and rescue spacecraft. Docking provisions for the OLV may also be provided, in which case the checkout and launch equipment would be located primarily on the OLF. If the OLV and OLF are separated during orbital operations, the checkout and launch equipment can be located on the OLF with remote checkout provisions, on the OSE with only monitoring and control capability on the OLF, or some combination between these extremes.

- Provide maintenance and repair facility for the OLF proper.

The prime advantages of the "permanent facility mode" of supporting an orbital launch have been stated by Ling-Temco-Vought in their final report, AOLO Report No. 00.368, Volume I as:

- Reduces Earth launch rates, putting lower demands on Earth launch facilities.

- Provides a base of operations with:

  a. larger maintenance and repair capability
  b. spares storage
  c. operational flexibility
  d. housing flexibility (for lodging additional checkout personnel)

- Orbital time and facilities available for other activities (R&D activities).

To fully realize these advantages, the OLF must provide more than the OLF "minimum" requirements listed above. A custom facility design appears essential, but one in which existing design concepts such as MORL are used to the maximum extent possible. The potential developmental cost savings and the progressive use of our expanding technology offer sufficient incentive to warrant a determined effort to utilize such systems which are presently in development or in advanced study stages.

4.1.2.3 Objectives & Guidelines. - The preceding considerations resulted in the establishment of basic mission and systems objectives and associated guidelines for the Initial OLF as shown in Figure 4.1-3.

FIGURE 4.1-3 -- BASIC OLF SYSTEMS OBJECTIVES & STUDY GUIDELINES

1. Initial OLF systems should provide:

   a. Lodging for OLF, checkout, and mission personnel during orbital launch operations, and for OLF personnel during waiting periods between orbital launches, with overload provisions for short periods.

   b. Hangar facilities for OSE and rescue and logistics spacecraft if necessary.

   c. Storage facilities for OLF, OLV, tanker and OSE spares and supplies.

   d. Facilities for OLV, OSE, tanker, and logistics spacecraft docking.

   e. Facilities for maintenance and minor repair of OLF, OLV, OSE, and rescue and logistics spacecraft.

   f. Facilities for propellant transfer and servicing of the OLV and OSE.

2. The facility should utilize planned hardware as much as possible. Following the initial parametric configurations analysis portion of the study, utilization of the Douglas MORL Module (6 to 9-man) appeared feasible and the use of such was so directed by NASA.

3. From the launch and assembly operations standpoint the OLF should be launched with a single Saturn V, if possible, or with as few other launches as possible. Rendezvous, docking, and assembly operations should be minimized.

4. The operational lifetime of the OLF should be at least five years at an orbital altitude of about 535 km (289 n. mi.).

For the initial OLF study these became the preliminary OLF requirements. More detailed design and operational objectives and guidelines are presented in the applicable sections of this report, wherein the particular subjects are discussed and the implications of the objectives, guidelines, and assumptions are more easily understood.

4.1.3 OLF Mission Operations. - Operations involving the OLF can be divided into four phases: (1) Prelaunch; (2) Launch, Orbital Assembly and Checkout; (3) Orbital Launch Operations; and (4) Scientific and R&D Operations (routine OLF operations for phases (3) and (4) are identical). Although some of the operations that might fall in the Prelaunch Phase, such as OLF ground assembly and testing, shipping, mating to the launch vehicle, etc., may impose some constraints on the orbiting facility's design, these constraints should be minor and primarily involve design details. Certainly, OLF size, shape, and weight distribution limitations set by the Earth launch vehicle are major constraints, but are considered launch systems limitations and not prelaunch operations limitations.

The Scientific and R&D Operations on board the OLF were given separate considerations, particularly with respect to the design effects of accomplishing such activities. A part of Section 6.2 covers the R&D scientific experiments possible aboard the initial OLF and the design changes required to accomplish additional experiments. Therefore, the prime considerations in this part of the study were the second and third operational phases stated above, i.e., the Launch, Orbital Assembly and Checkout Phase, and the Orbital Launch Operations Phases, respectively.

Early in the study it became apparent that within the Orbital Launch Operations Phase, a study interface existed between the associated AOLO contractors (LTV, Boeing, and Lockheed) that required clarification to prevent unwarranted duplication and yet provide for a complete coverage of this portion of the study. It was, therefore, agreed that the OLF study would be completely responsible for the analysis of the OLF Launch, Orbital Assembly and Checkout Operations, but would be confined to the station operation, including integrated OLF maintenance and repair and logistics operations, during the Orbital Launch Operations. Lockheed's SCALE Study was to provide the analyses of the checkout and launch activities, which included docking, checkout, servicing, maintenance, etc. of the OLV and tankers; and LTV, in their AOLO Study, were to analyze similar activities with respect to whatever OSE was required, if any, and to integrate the overall operations. Within these interface definitions, the OLF Operational Studies proceeded with the goal of providing systems functional requirements for the primary design effort, operational feasibility verification for design concepts, and operational task definitions for crew requirements analysis.

4.1.3.1 OLF Launch, Orbital Assembly & Checkout Operations - General Description. - Prior to any detailed analysis of the operations involved in launching the OLF into orbit, erecting deploying or assembling it in orbit, and checking it out, it was necessary to have some reasonable idea of what such a support facility might look like. Preliminary operational requirements and systems functional requirements were established as discussed in OLF Mission Objectives and Associated Study Guidelines, Para. 4.1.2, and as accumulated from existing OLO and Space Station Studies. These requirements provided the basis for the initial parametric configuration design studies discussed in Para. 5.2. More detailed operations analysis for this phase was then dependent upon the particular configuration being considered.

Three concepts were investigated in the development of the OLF from the completion of the parametric studies to the selection of the baseline configuration on which the detail design iteration studies were made. The first such concept evolving from the variety considered in the parametric studies was one which attempted to make use of as much existing or planned hardware as possible. This concept is referred to in this report as OLF Concept Alternate 2. A simplified pictorial representation of the Launch and Assembly Operations of Alternate 2 is shown in Figure 4.1-4. A detailed listing of operational events of this concept extending from the pre-(earth)-launch of the facility through the post-orbital-launch operations is presented in Figure 4.1-5 to illustrate the total operations required from pre-earth-launch activities through post-orbital-launch activities. The primary operational analysis of the Baseline Concept only considers those operational phases which have significant effects on the design of the OLF. The basic design concept of Alternate 2 is discussed more fully in Para. 5.2, but basically utilizes MORL Modules, LEM Adapter Assemblies, Apollo Service and Command Modules, and a Gemini emergency return vehicle. This concept requires four Saturn I-B launches. The first and second launches are identical, each launching and injecting into a 535 km orbit a single unmanned MORL Module. The third and fourth launches are manned and also nearly identical, including a LEM Adapter Assembly and Apollo Service and 3-man Command Module in each of their payloads, however a docking hub is carried in the LEM Adapter Assembly of the third launch system and a Gemini return vehicle can be carried in a similar position of the fourth launch system. Following injection of the third and fourth launch vehicles' payloads into a 185 km parking orbit and jettisoning of the second stages, the Command Modules are moved to the stowage positions on the aft skirt of the LEM Adapter Assemblies. The docking hub and Gemini return vehicle are moved from their positions within the LEM Adapter Assemblies to exterior stowage positions opposite the Command Modules. Each assembly is then propelled, via the Service Module propulsion system to the 535 km orbit and rendezvoused with the waiting MORL Modules. The modules are mated and the two MORL Module/LEM Adapter Assemblies (referred to in Figure 4.1-5 as OLFA-1 & -2) are rendezvoused. The docking hub is installed and the two major assemblies are mated. The Command Modules are transferred to the aft docking port of the MORLs, and the Gemini return vehicle to a docking port at the hub. The solar panels are deployed, systems activated and tested, and the OLF is ready for orbital launch or research operations. The remainder of the checkout, OLF, and OLV crew members are transported to the facility on subsequent logistics launches. Complexity of the launch and assembly operations for this concept are somewhat apparent in Figure 4.1-4 and Figure 4.1-5, but become overwhelming in an event-logic network analysis. However, the basic assembled configuration of OLF Alternate 2 offered numerous desirable features, including the operational capability for hard-docked-orbital checkout and propellant transfer operations as well as separated operations. Other desirable features are enumerated in Paragraph 5.2.

The operational complexity of OLF Alternate 2 made it fairly evident that a concept which would require fewer rendezvous, docking, and assembly operations, and yet retain as many of the desirable features of that assembled configuration as possible, was highly desirable. An attempt was made to package this or a similar configuration onto one booster. From this effort evolved the Baseline Concept which through detail iteration became the initial OLF. The baseline used solar panels for power, but the evolved initial OLF used an Isotope-Brayton cycle. The operational event descriptions, shown in Figure 4.1-6, reflects the latter configuration. The OLF shown in this figure is launched by a single Saturn V. At launch the two MORL Modules are telescoped within the cylindrical sections on each end of the docking hub. Topping the vehicle is a six-man Apollo, in which five of the crew (part OLF and part checkout personnel) are carried into orbit. The first event following Earth launch is separation of the S-IC stage, followed by injection into an elliptical transfer orbit of 185 km (100 n. mi.) perigee and

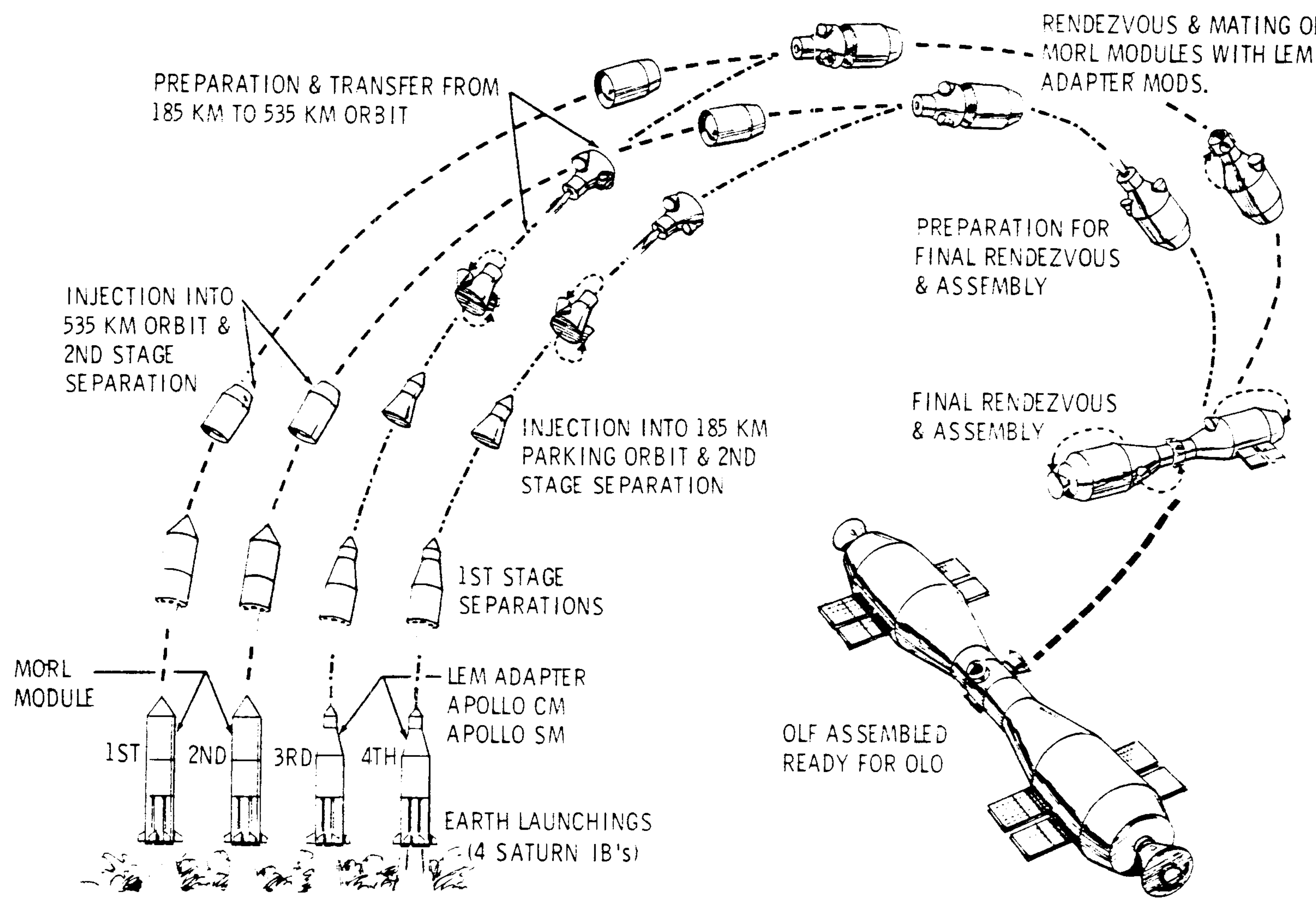


Figure 4.1-4 ALTERNATE 2 - OLF LAUNCH AND ASSEMBLY

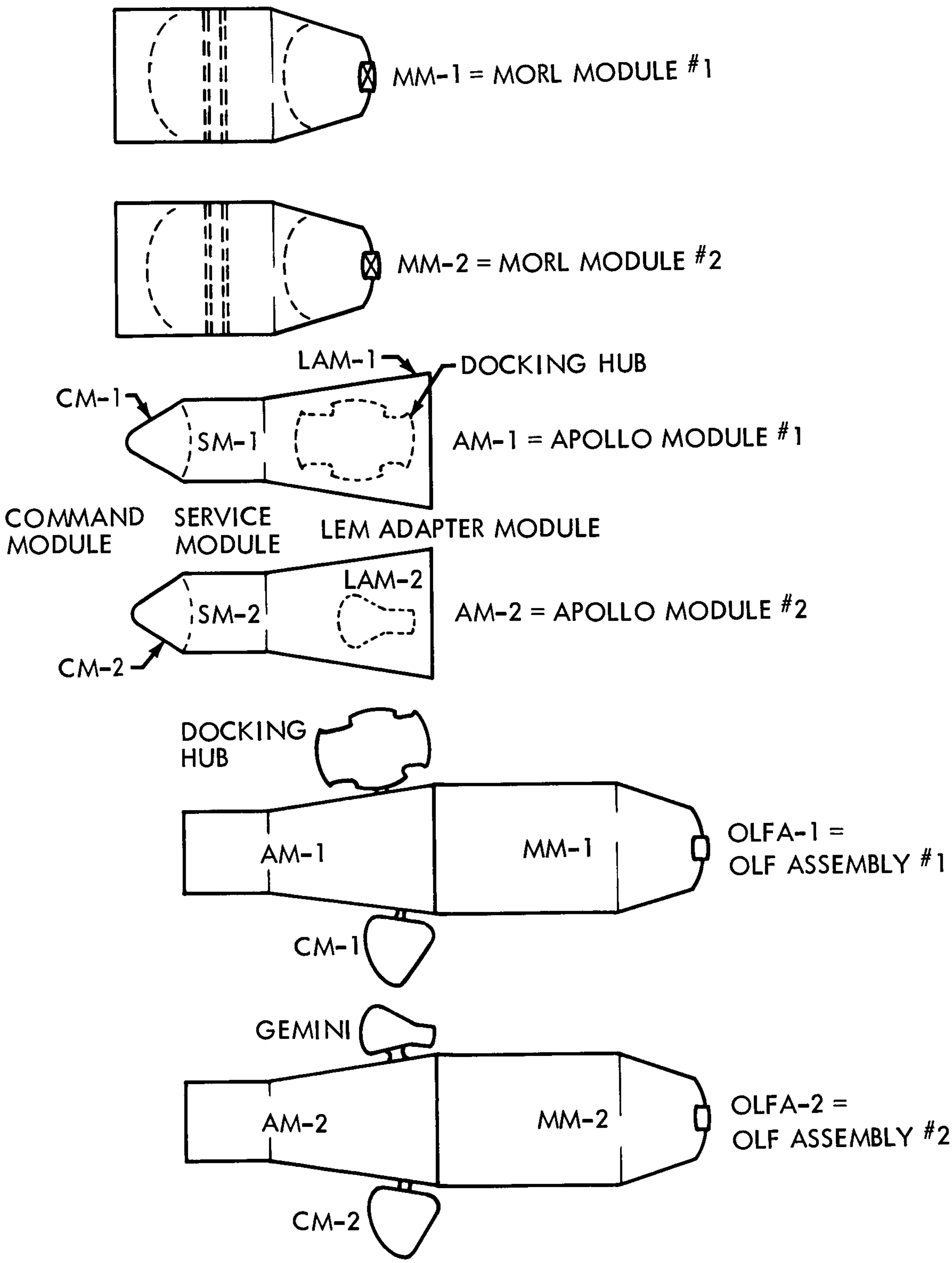


Figure 4.1-5 OLF CONCEPT – ALTERNATE 2 OPERATIONS

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

A. PRELAUNCH OPERATIONS

1. Factory checkout of OLF subassemblies,
2. Packaging of OLF subassemblies,
3. Shipment to Cape Kennedy,
4. Receive and inspect OLF subassemblies (MM-1 & 2, CM-1 & 2, SM-1 and 2, LAM-1 & 2, Docking Hub, Gemini Entry Vehicle) to OVC bldg.,
5. Modify and repair assemblies as required,
6. Perform detailed subsystem checks,
7. Transfer subassemblies to fluid test complex (MMs, CMs, SMs & Gemini),
8. Perform propulsion system and RCS functional tests,
9. Transfer subassemblies to environmental control systems bldg., (MMs, CMs, SMs and Gemini),
10. Mate SMs to CMs,
11. Perform EC/LS systems functional tests (MMs and CM/SMs),
12. Transfer subassemblies to space chamber facilities (MMs, CM/SMs, LAMs, Docking Hub and Gemini),
13. Assemble CM/SMs to LAMs,
14. Assemble MMs to AMs in simulated space environment,
15. Mate docking hub to SM-1 in simulated space environment,
16. Perform complete OLF systems checkout in simulated space environment,
17. Disassemble docking hub from SM-1 and MMs from LAMs,
18. Transfer subassemblies to weight and balance building,
19. Perform weight and balance of OLF subassemblies,
20. Transfer OLF subassemblies to launch pad,
21. Emplace OLF subassemblies (MMs or AMs as applicable) on launch vehicle,
22. Perform compatibility tests of space vehicle,

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

23. Perform integrated space vehicle tests,
24. Conduct simulated flight test,
25. Accomplish final countdown preparations,
26. Conduct countdown,
27. Repeat steps 1 through 21 for required backup assemblies.

B. LAUNCH ORBITAL ASSEMBLY & CHECKOUT

1. Launch of MORL Module #1 (MM-1),
2. Injection of MM-1 into 185 km parking orbit,
3. Preparation for transfer to 535 km assembly orbit,
    a. Jettison unnecessary fairings,
    b. Release antennas,
    c. Activate MM-1 telemetry and digital command systems,
    d. Command activation of MM-1 tracking aid system,
    e. Command tape recorders "ON",
    f. Command reaction control and stabilization and control systems "ON",
    g. Terminate S-IVB control and electronics functions.
4. Transfer MM-1 to 535 km assembly orbit,
5. Confirmation of orbit achievement and activation of basic systems,
    a. Verify desired orbit has been achieved,
    b. Command MM-1 to proper orientation with sun,
    c. Deploy solar panels,
    d. Verify proper output from solar panels,
    e. Connect solar panel power to electrical power bus,
    f. Activate battery charging circuits.
6. Remote checkout and confirmation of operability of MM-1 subsystems,

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

a. Command checkout of reaction control and stabilization and control systems,

b. Command checkout of electrical power system,

c. Command checkout of environmental control and life support systems,

d. Command checkout of mechanical systems,

e. Command checkout of communication systems,

f. Command checkout of data processing systems,

g. Deactivate systems not required for orbit control.

7. Repeat steps 1 through 6 for MM-2,
8. Launch of AM-1 with 5-man crew,
9. Injection of AM-1 into 185 km parking orbit and wait,
10. Transfer of AM-1 to 535 km assembly orbit,
11. Transfer of CM-1 from nose of AM-1 to aft side of LAM-1,
12. Maneuvering of AM-1 to rendezvous with MM-1,
13. Removal of OLF docking hub from LAM-1 and attachment to aft side of LAM-1 opposite CM-1,
14. Docking and attachment of AM-1 with MM-1,
15. Crew transfer from CM-1 to MM-1 through hatch and accessway in LAM-1,
16. Inspection of assembled OLFA-1,

a. Connect spacesuits into MORL suit loop connections,

b. Check suit loop for proper operation,

c. Establish communications with Earth and between MORL stations,

d. Establish capability to monitor and control CM-1 from the MORL,

e. Inspect MORL structure for evidence of damage incurred during or after Earth launch,

f. Inspect seals at airlock, windows, hatches, etc.,

g. Check security of mounting of all equipment, cabling, plumbing, etc.,

h. Check plumbing and equipment for fluid or gas leaks,

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

i. Check charge condition of batteries.

17. Checkout and calibration of checkout systems,

18. Activation and checkout of OLFA-1 subsystems,

a. Activate MORL control and maintenance consoles,

b. Check consoles for correct indications and operation during checkout of individual subsystems,

c. Checkout operation of atmosphere supply and pressurization control subsystem -

- Check quantities of expendable supplies,
- Check regulation of atmosphere to proper O_2 to N_2 ratio,
- Check regulation of system pressure and temperature,
- Check controls and displays for proper operation and indications,
- Check spacesuit outlets for proper interface with spacesuits,
- Check capability of vacuum pump to pump-down hangar and airlock,
- Check pump down times, cooling fluid temperature, storage tank final pressure and temperature.

d. Checkout operation of atmospheric control and purification system -

- Check airflow rates, temperatures and humidity levels at applicable points in the system,
- Check system capability of maintain minimum contaminant and CO_2 levels,
- Check operation of backup electrical heater,
- Check controls and displays for proper operation and indications.

e. Checkout operation of water management system -

- Check water quantities, temperatures and pressures at applicable points in the system,
- Check operation of water evaporator,
- Check for system capability to maintain proper water flow rates,
- Check operation of sensors for ability to detect contamination,

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

- Check portable fill hose for compatibility with all water tanks,
- Check controls and displays for proper operation and indications.

f. Checkout operation of cabin conditioning system -

- Check operation of system temperature sensors and control of heat exchanger,
- Check suit connectors for proper operation and correct output,
- Check controls and displays for proper operation and indications.

g. Checkout operation of waste management system -

- Check that system pressure and temperature adequate for dehydration of wastes,
- Check system for leakage when pressurized,
- Check relief valve setting and control valve operation.

h. Checkout structure and mechanical systems -

- Check operation of solar panel control system,
- Check operation of centrifuge,
- Check operation of all stowage arm assemblies,
- Check operation of docking port mechanisms
- Check engagement and disengagement of electrical, mechanical and resupply umbilicals,
- Check all seals and plumbing for leakage.

i. Checkout operation of reaction control system -

- Pressurize reaction control system,
- Check pressures of tanks, plumbing, valves as applicable,
- Check system and plumbing for leaks,
- Check operation of propellant transfer and purging systems,
- Verify capability of leak detection system to detect leaks,
- Check regulator and relief valve settings,

FIGURE 4.1-5 -- OLF ALTERNATE 2 -- OPERATIONS - Continued

- Check operation of reaction control engines,
- Check operation of all redundant systems and components,
- Check controls and displays for proper operation and indications.

j. Checkout operation of stabilization and control system -

- Check acquisition capability of sun and horizon sensors,
- Check operation of control moment gyros function as momentum storage devices,
- Check system capability to maintain lab orientation,
- Check functional capability of manual maneuvering mode,
- Check operation of redundant electronic control circuits,
- Check controls and displays for proper operation and indications.

k. Checkout operation of communications and telemetry system -

- Check all modes of operations of communications links,
- Check capability of telemetry system to convert data into format required for transmission,
- Check capability of digital command system to receive and react properly to received signal commands,
- Check operation of tape recorders,
- Check operation of television cameras, monitoring system, camera control circuits and television transmitters,
- Check operation of acquisition beacon and radar transponder,
- Check operation of data processing and computing system,
- Check controls and displays for proper operation and indications,

l. Checkout operation of electrical power system -

- Check capability of system to control, switch and distribute power throughout the system including redundant circuits,
- Check output of batteries and solar panels,
- Check voltage regulation, battery charging and static

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

inverter operation,

- Check controls and displays for proper operation and indications.

m. Checkout operation of on-board test subsystem,

- Check capability of test subsystem to command and monitor lab systems in the performance of above checkout operation,

- Check operation of audio and visual alarm circuits,

- Check capability of manual test equipment (VTVM, scope, counter, signal generator, etc.) to perform specified functions.

19. Repetition of steps 8 through 11 for AM-2 (4 men launched in AM-2),

20. Maneuvering of AM-2 to rendezvous with MM-2,

21. Removal of 2-man Gemini entry vehicle from LAM-2 and attachment to aft side of LAM-2 opposite CM-2.

22. Docking and attachment of AM-2 with MM-2,

23. Confirmation of orbital positions of OLFA-1 and OLFA-2,

24. Transfer of at least two crew members from MM-1 through LAM-1 to CM-1 aft attachment of LAM-1,

25. Rendezvous OLFA-2 with OLFA-1,

26. Removal of docking hub from aft side of LAM-1 and installation in engine end of SM-1,

27. Docking and attachment of OLFA-1 and OLFA-2 at the docking hub,

28. Transfer of CM-1 to aft docking port of MM-1,

29. Crew transfer from CM-1 to MM-1,

30. Transfer of CM-2 to aft docking port of MM-2,

31. Crew transfer from CM-2 to MM-2 except two men remain in CM-2,

32. Crew transfer from CM-2 to Gemini entry vehicle at aft attachment point of the LAM-2,

33. Transfer of Gemini entry vehicle to aft attachment point on MM-2,

34. Crew transfer from Gemini to MM-2,

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

35. Inspection of OLFA-2 (same as step 16),

36. Activation and checkout of OLFA-2 subsystems (same as step 18),

37. Stabilization of OLF and orbit confirmation.

C. ORBITAL WAIT AND STATION KEEPING

1. Monitor OLF systems operation,

2. Maintain OLF systems as required,

3. Control OLF orbital altitude as required,

4. Control OLF attitude as required for solar panel orientation, thermal or radiation environment, etc.,

5. Coordinate with Earth on OLV schedule, problems encountered, etc.,

6. Conduct biomedical and behavioral tests of crew members,

7. Conduct training activities to acquire experience in problems associated with zero-g environment (donning spacesuits, use of airlock, extra-vehicular activity, use of tethers and restraints),

8. Continue crew normal daily routines,

9. Maintenance of systems and personnel readiness and operability throughout the orbital launch operations (details similar to those of II.b.1 above),

10. Monitoring and direction of rendezvous of 3rd APOLLO COMMAND MODULE (CM-3), carrying the mission crew (3 men) and the remaining OLO support personnel (if required),

11. Direction of docking CM-3 to OLF docking port on spin axis,

12. Transfer of crew from CM-3 to OLF,

    NOTE: at a later time when OLF is not spinning, the CM-3 can be moved to a parking position, attached at the aft attachment point of MM-1.

13. Monitoring and direction of overall logistics operations, including call-up, rendezvous and docking of logistics carriers loaded with personnel, spare parts and supplies, the return of crews to Earth and orbital garbage handling (routine and emergency logistics operations),

14. Monitor total OLO.

FIGURE 4.1-5 -- OLF ALTERNATE 2 - OPERATIONS - Continued

D. ORBITAL COUNTDOWN AND LAUNCH

1. Same as items of C above with the exception of training activities and biomedical and behavioral tests, which will be reduced to a minimum during this time.

2. Tracking of OLV through launch phase until such time that DSIF can proceed independently.

E. POST ORBITAL LAUNCH

1. Continuation of D2 above.

2. Provision of computational and advisory assistance to OLF as required.

3. Communications relay between OLV and Earth as required.

4. Refurbishment of OLF launch support systems as required.

5. Transfer of launch support crews back to Earth.

6. Replacement of launch support crews in OLF by experimental crews.

7. Servicing and checkout of experimental equipment.

8. Activation of experiments.

9. Monitoring and direction of orbital experiments.

10. Direction of routine logistics operations.

F. SECOND ORBITAL LAUNCH - PRELAUNCH OPERATIONS

1. Shutdown of experiments which could interfere with orbital launch operations support.

2. Transfer experimental personnel to Earth.

3. Replacement of experimental crews with the required launch support personnel.

4. Replenishment of OLV and OSE spares stored on board the OLF.

5. Replenishment of orbital servicing supplies as required.

6. Inspection and checkout of OLF equipment.

7. Maintenance and repair of equipment as required.

8. Repeat of operations C of first pre-orbital launch.

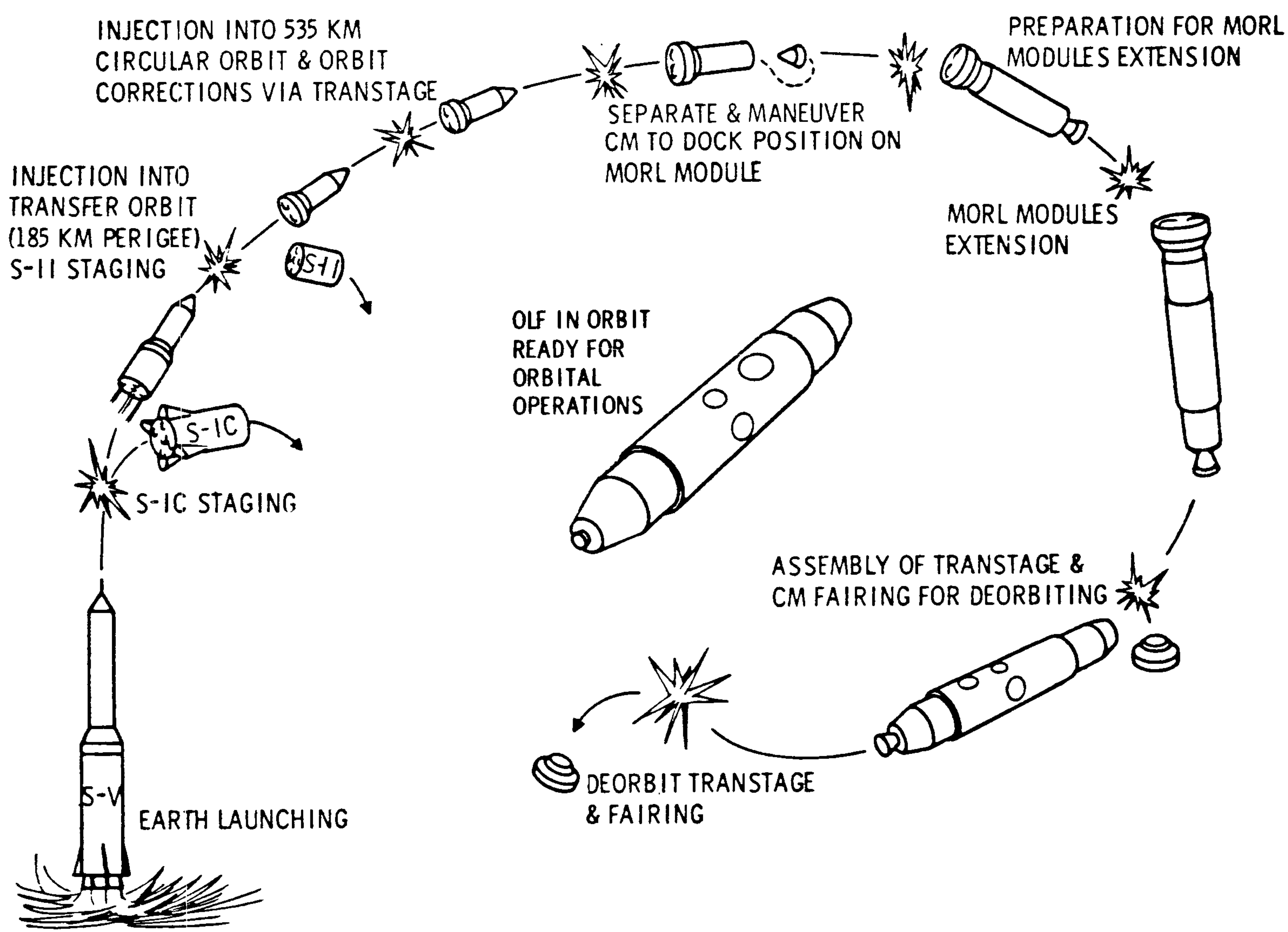


Figure 4.1-6 INITIAL OLF LAUNCH & ERECTION

535 km (289 n. mi.) apogee. The S-II stage is then jettisoned and, upon arrival at the 535 km apogee, the injection stage propulsion unit is fired to circularize the orbit at that altitude. The Command Module with its fairing then separates from the rest of the assembly, maneuvers into position, and nose docks with the MORL Module. Life support systems of the first MORL are remotely activated and the crew transfers from the Command Module into the MORL. The MORL Modules are extended to their outer positions, antennas are deployed, the Command Module fairing is attached to the injection stage, and the two are separated from the OLF and deorbited. All OLF systems are activated and checked out and the OLF is ready to participate in orbital launch or research operations. The remainder of the checkout and OLF crew are delivered to the facility on subsequent logistics launches. In addition to the simpler launch and assembly operations of this concept compared to Alternate 2, there are several design advantages in this concept. One such advantage is the increased working and storage volume of the hub and cylindrical sections between the MORL Modules as compared to the LEM adapter assembly and the small docking hub of Alternate 2. These additional volumes allow for more extensive interior activities, which are particularly of interest around the docking hub where other vehicles may be docked for unloading, checkout, repair, servicing, etc.

Following the development of the OLF baseline concept from which the initial OLF evolved, an attempt was made to break the assembled baseline configuration down into launch packages suitable for launching on board smaller boosters, such as the Saturn I-B. This was a digression back to a more complex operation, from a launch and assembly operations standpoint, but it does offer the design and associated operational advantages of the baseline concept, with the flexibility offered by the capability of multiple launches by smaller boosters with relatively minor conceptual changes from the baseline concept. This concept is considered OLF Alternate 1 and the launch and assembly operations for this concept are portrayed in Figure 4.1-7. In this figure the facility is shown being launched aboard three Saturn I-Bs. The first Saturn I-B launched is topped by the docking hub section of the hub and hangar assembly and the Command Module carrying five crew members. This is the first payload boosted into the 535 km orbit where it awaits subsequent launches. The second launch includes an injection stage propulsion unit, a telescoped MORL Module, and nose fairing. This payload is injected into a 185-km parking orbit from which the injection stage propulsion propels it to the 535-km orbit and to a rendezvous with the hub section and Command Module. While in a rendezvous position, the CM separates and maneuvers to a docked position with the MORL Module; the injection stage and CM fairing are separated from their launch positions attached to one another and deorbited, and the hub section and hangar section (within which the MORL Module is telescoped) are mated. The third launch includes an injection stage and the other MORL Module telescoped within a hangar section and nose fairing. This launch follows the same sequence as the second launch, via the parking orbit, the injection into the 535-km orbit, and the rendezvous with the waiting assembly using the injection stage propulsion. The injection stage is separated and deorbited and the MORL Module and hangar section are mated to the waiting assembly. The MORL Modules are extended, antennas deployed, subsystems activated and checked out and the OLF is ready to participate in orbital launch or research operations. The remainder of the OLF and checkout personnel are delivered to the facility on subsequent logistics launches.

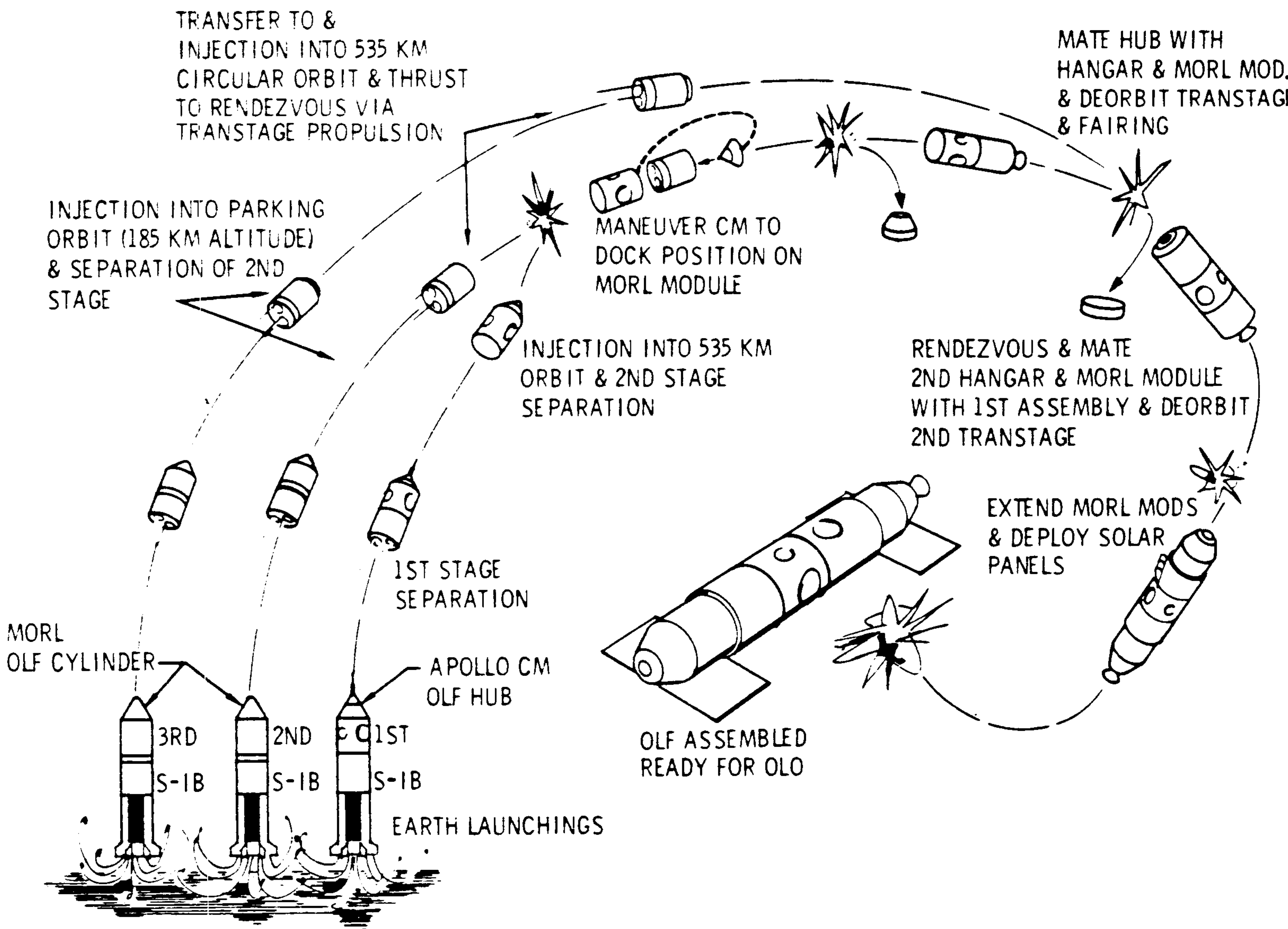


Figure 4.1-7 ALTERNATE 1 - OLF LAUNCH & ASSEMBLY

Payload packaging for the use of additional boosters was also studied. Certain advantages are available when more than three boosters are used. For example, greater structural integrity can be built into the design, in addition greater amounts of spares, expendables, and other payload can be includ in the original launches. In the case of launch by four Saturn I-B boosters, the payloads would be one MORL on each of two boosters, the cylindrical sections retracted one into the other on a third booster and the Apollo CM and OLF hub on a fourth. In the case of launch by five Saturn I-B boosters, the payloads would be one MORL on each of two boosters, one cylindrical section on each of two boosters and the Apollo CM and OLF hub on a fifth. Another advantage of the greater number of boosters is the possibility of considering lower rated boosters than when only three are used.

Comparisons of these three OLF concepts and the selection of the recommended configuration is discussed in the Design Integration - Baseline Selection discussions of this report, Para. 5.2, hence will not be repeated herein except to state that the choice of the OLF baseline concept was made primarily on the basis of design and operational simplicity, which in this case implies higher probability of mission success.

4.1.3.2 Detailed Analysis - OLF Launch, Assembly & Checkout - Initial Concept. As discussed in preceding paragraphs, the OLF launch, orbital assembly and checkout phase, and the orbital launch operations phase are considered to impose the most significant operational constraints upon the Orbital Launch Facility's design; hence, these phases were given prime consideration in this part of the study. The launch and orbital assembly operations of each of the three OLF concepts have been described briefly and pictured in the preceding figures. A sequential listing of the major operational events required for the initial OLF concept launch, orbital assembly and checkout is presented in Figure 4.1-8. Configurations sketches for the initial OLF package for launch and in the extended orbital configuration are shown in Figure 4.1-9 for nomenclature reference.

FIGURE 4.1-8 -- INITIAL OLF LAUNCH, ORBITAL ASSEMBLY & CHECKOUT - MAJOR EVENTS

1.1 OLF launch and orbital injection

- 1.1.1 Launch and injection into elliptical transfer orbit (185 km perigee and 535 km apogee),
- 1.1.2 Transfer and injection into 535 km circular orbit at transfer orbit apogee.

1.2 OLF extension, assembly & checkout

- 1.2.1 Separation and redocking of Apollo Command Module,
- 1.2.2 Remote activation of MORL Module-1 environmental control system,
- 1.2.3 Crew transfer from Command Module to MORL Module-1,
- 1.2.4 Extension of MORL Modules 1 and 2,

FIGURE 4.1-8 -- INITIAL OLF LAUNCH, ORBITAL ASSEMBLY & CHECKOUT - MAJOR EVENTS -- Continued

1.2.5 Deployment of antennas and activation of primary communications and tracking aids systems,

1.2.6 Assembly and deorbiting of injection stage and Command Module fairing,

1.2.7 Activation and checkout of all OLF subsystems,

1.2.8 Repairs.

The major events of Figure 4.1-8 were established by an event-logic analysis, the network of which is shown in Figure 4.1-10. The first block in the network, "Pad Work and Countdown", was included merely to provide the sequential event which completes the loop for alternate action in case of systems or operational failures. The numbers appearing in the major events of Figure 4.1-8 correspond to the first numbers appearing above the major events blocks in the network. These numbers are carried through the function and task analysis and timeline analysis for easy reference purposes. The numbers in the parentheses above each major event block indicate the time in hours from Earth launch of the OLF until that particular event is completed in a nominal mission (i. e., a mission in which no failures requiring alternate action are encountered). These times were established by the function and task analysis and crew utilization timeline analysis portions of this study which will be discussed in following paragraphs. Obviously, if failures did occur, alternate action would be required as shown, and the timing would be different than that presented. The method of time phasing the OLF launches within the total orbital launch operations, taking into consideration the possibility of failures, is also discussed in later paragraphs. Suffice it to say here that the total time requirement for the OLF launch, assembly, and checkout (approximately 55 hours) is such a small increment of the total OLO time, that a detailed analysis of failure probabilities for each event and a determination of alternate action time requirements were not warranted in this study; nor is there sufficient statistical information available at this time concerning these types of operations. A computer program to analyze these conditions could be established and could be very useful in more detailed studies of this nature and perhaps in more accurately predicting the probability of mission success. Such a computer program should probably be incorporated as a subroutine in the total OLO simulation computer program.

Following the definition of major operational events, the operations analysis proceeded with a function and task analysis, wherein individual tasks required to accomplish the major events were first identified. The detailed function and task analysis sheets comprise Figure 4.1-11. Column 1 of the function and task analysis forms lists the major events with numbers corresponding to those of the event-logic network blocks. Columns 2 and 3 list the tasks and a brief indication of what the procedure is for accomplishing the task. The dash number in Column 2 is used for task identification; for example, the second task for major event 1.2.1 would be 1.2.1-2. Columns 4, 5, and 6 provide personnel information, including the number of persons and general skills required to perform the task and, for presentation purposes, the crewmen assigned to perform the tasks are shown as

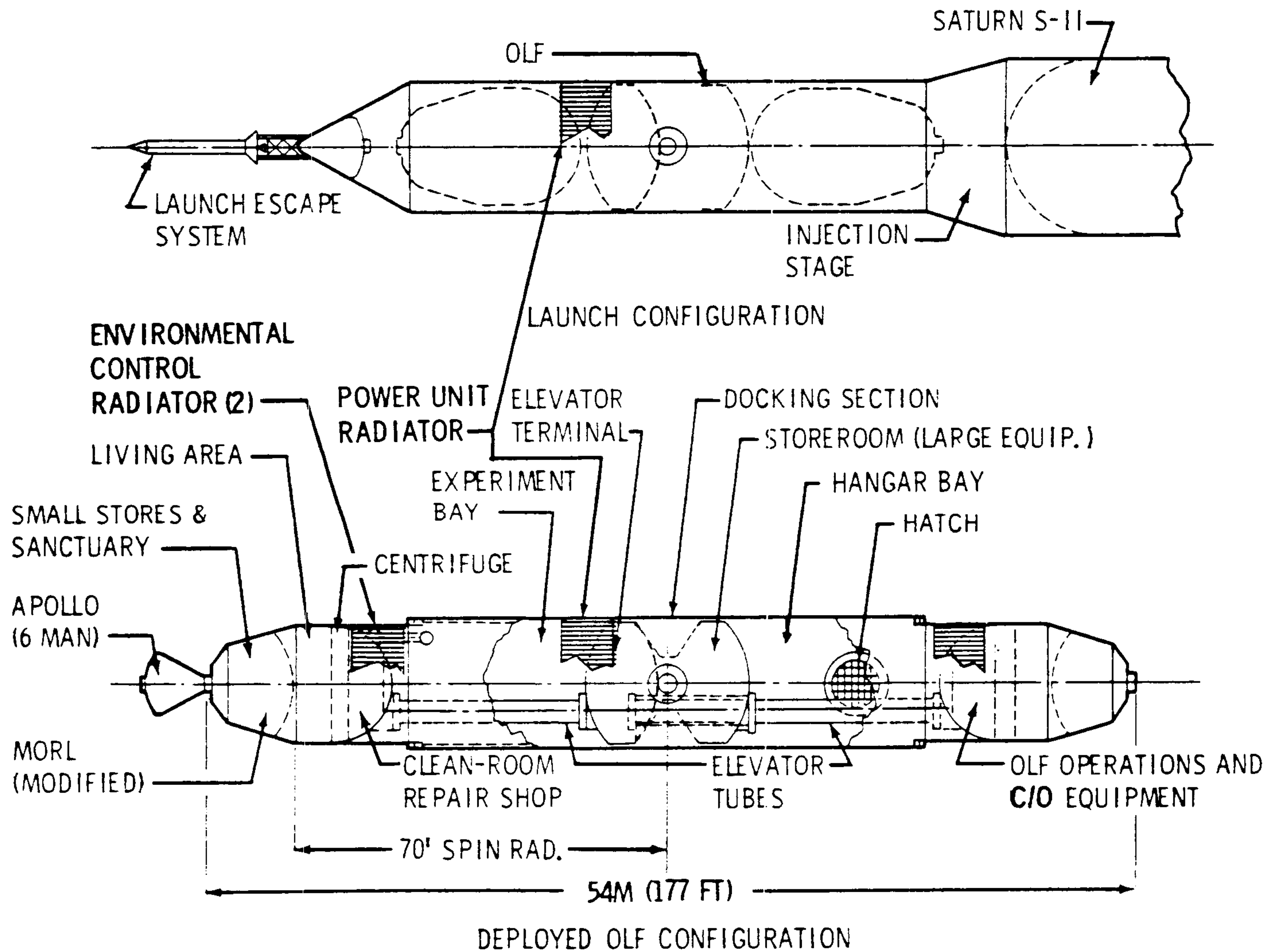
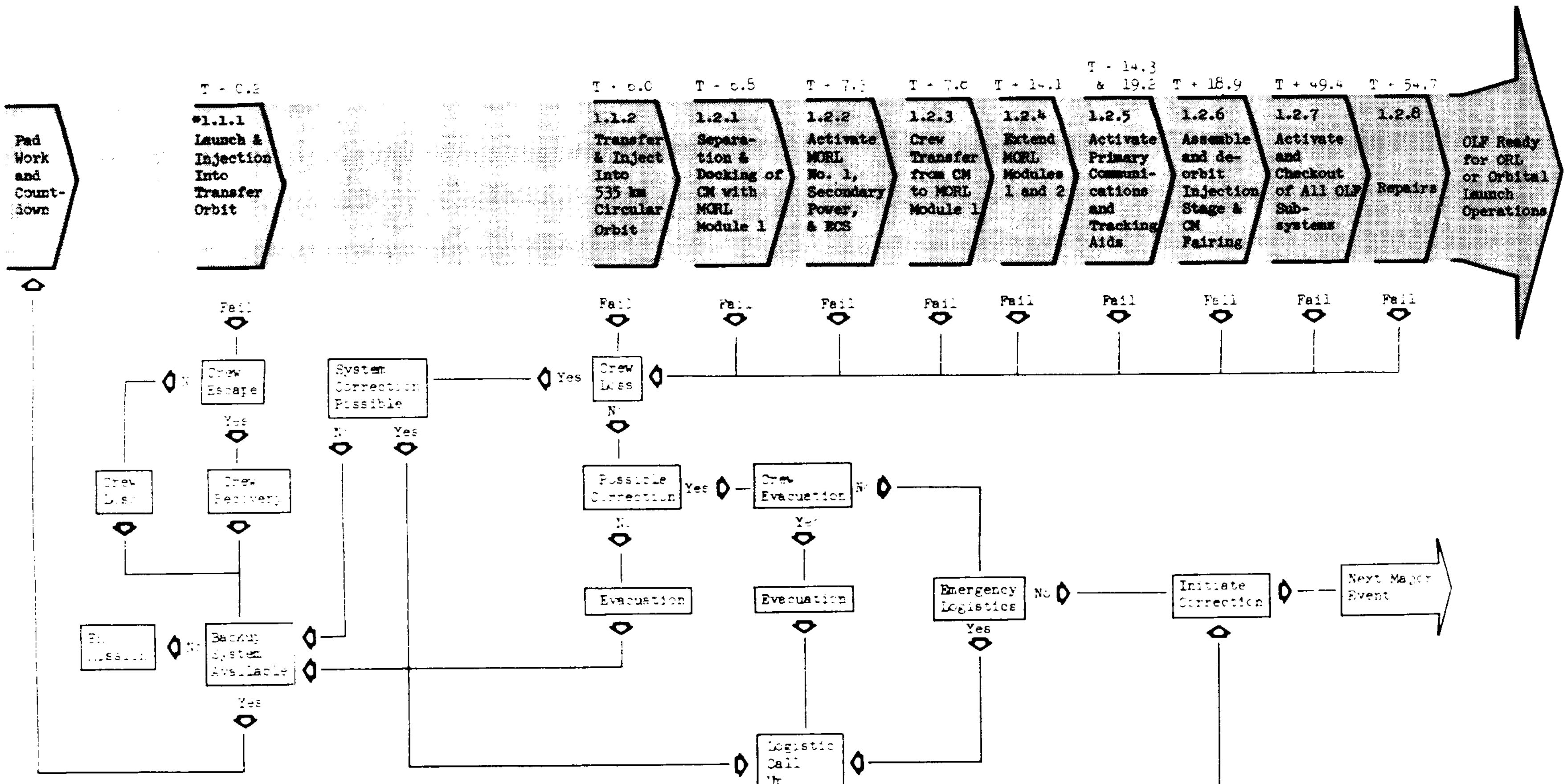


Figure 4.1-9 INITIAL OLF DESIGN CONCEPT



* The first numbers shown are the event numbers appearing on the Function & Task Analysis Sheets. The times appearing in the parentheses are hours from Earth launch of the facility and indicate the time at which the event is completed if no failures are encountered; these times are derived from crew utilization charts.

Figure 4.1-10 BASELINE OLF LAUNCH, ORBITAL ASSEMBLY AND CHECKOUT LOGIC NETWORK

MAJOR EVENTS	TASKS: DESCRIPTION	TASKS: PROCEDURE	PERSONNEL: NO. PERSONS	PERSONNEL: SKILLS REQUIRED	PERSONNEL: CREW ASSIGNED	TIME: ELAPSED	TIME: MAN-MINS. PER TASK	TIME: ACCUM. MAN-MINUTES	TIME: SEQUENCE LIMITATIONS	EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
1.1.1 OLF launch & injection into elliptical transfer orbit (185 km perigee & 535 km apogee)	(-1) Monitor & read-systems' performance	. Visual observation & radio communication	2	Flight Command	FCO & E/E	12 mins	24	24	initial task	Apollo CM & S-II Thrust Control Sys.	Apollo Command Module	
	(-2) Control thrusting of S-II stage for injection into transfer orbit.	. Command control							follow 1.1.1-1			
1.1.2 Transfer & injection into 535 km circular orbit	(-1) Terminate S-II stage control	. Pushbutton control							follow 1.1.1-2 &	Apollo CM	Apollo Command	
	(-2) Separate S-II stage	. Pushbutton control							follow 1.1.1-1 &	S-II and injection stage control sys.		
	(-3) Monitor & readout systems' performance	. Visual observation & radio communication	2	Flight Command	FCO & E/E	46 min	92	116	follow 1.1.2-2			
	(-4) Receive flight instructions for circularizing orbit at 535 km apogee	. Radio communications							follow 1.1.2-3			
	(-5) Control injection stage thrusting for circularizing orbit.	. Command Control				2 min	4	120	follow 1.1.2 4			
	(-6) Confirm orbit achievement, make necessary corrections & monitor systems' performance	. Radio communications Command Control & Instrument observation	1+ see remarks		FCO & CO	285 min	360 see remarks	480	follow 1.1.2-5			285 minutes (approx. 3 orbits) during which FCO & C/O alternately monitor systems operation for 40 mins. each orbit and simultaneously observe and make corrections for 20 mins. per orbit.
	(-7) Terminate injection stage control at CM	. Electrical switching at CM console	2		FCO & E/E	2 min	4	484	follow 1.1.2-6			
1.2.1 Separation & redocking of Apollo Command Module	(-1) Disconnect control linkage with CM	. Pushbutton control							follow 1.1.2-7	Apollo CM Separation System & MORL Docking Mechanisms	Apollo Command Module	
	(-2) Check and adjust attitude stabilization.	. Visual observation of instrumentation & radio control	2	Flight Command	FCO & E/E	10 min	20	504	follow 1.2.1-1			Attitude control system of injection stage is used.
	(-3) Separate CM fairing from nose of launch assembly	. Squib firing by pushbutton control							follow 1.2.1-2			
	(-4) Maneuver CM 180° & nose dock at MORL docking port	. Command Control				30 min	60	564	follow 1.2.1-3			
	(-5) Mechanically secure CM to MORL Mod. 1	. Pushbutton control				5 min	10	574	follow 1.2.1-4			
1.2.2 Remote activation of MORL Module-1 Environmental control system	(-1) Signal from CM to MORL-1 to connect power to ECS.	. Radio Signal				10 min	10	584	follow 1.2.1-5	Apollo CM, MORL Electrical Power & Environmental Control System	Apollo Command Module	
	(-2) RF signal to activate ECS of MORL	. Radio Signal	1	Console Operation	E/E				follow 1.2.2-1			
	(-3) Confirm operation of MORL power & environmental control	. Visual observation of instrumentation				20 min	20	604	follow 1.2.2-2			
1.2.3 Crew transfer from Command Module to MORL Module-1.	(-1) Confirm CM-to-MORL seal and pressurize MORL airlock (100% O_2)	. Instrumentation & indicator observations	2	ECS & Console Opr.	LS/ECS (& FCO monitor)	5 min	10	614	follow 1.2.2-3	Apollo CM & MORL remote ECS monitoring instrumentation	Apollo Command Module & MORL docking & airlock areas	

Figure 4.1-11 FUNCTION & TASK ANALYSIS

MAJOR EVENTS	TASKS: DESCRIPTION	TASKS: PROCEDURE	PERSONNEL: NO. PERSONS	PERSONNEL: SKILLS REQUIRED	PERSONNEL: CREW ASSIGNED	TIME: ELAPSED	TIME: MAN-MINS. PER TASK	TIME: ACCUM. MAN-MINUTES	TIME: SEQUENCE LIMITATIONS	EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
1.2.3 (continued)	(-2) Crewmen enter MORL airlock, adjust atmosphere to that of MORL and enter MORL Module 1.	• Manual operations, valve manipulations & instrumentation observation	5	General & Console Opr.	Crew (& FCO monitor)	15 min	75	689	follow 1.2.3-1			
	(-3) Cursory check of MORL ECS & battery charge condition	• Visual inspection of instrumentation	2	ECS & Console Opr.	LS/ECS (& FCO monitor)	5 min	10	699	follow 1.2.3-2			
1.2.4 Extension of MORL Modules 1 and 2	(-1) Crewman at CM console remains in CM on semi-alert until extension has been completed	• This is a standby function wherein the crewman is only required to be available at an emergency signal	1	CM Console Opr.	FCO	315 min (see remarks)	see remarks		follow 1.2.3-3	Apollo CM	Apollo Command Module Control Console	This standby time on semi-elert status, therefore crewman can eat, relax, even sleep with proper signalling devices to make him available if required.
	(-2) Verify attachment of MORL 2 storage arms to injection stage & initiate release of injection stage from shell structure of hangar bay.	• Electrical signals from OLF operations console & observation of indicator instruments	2	OLF Console Opr.	E/E & S/M	5 min	10	709	follow 1.2.3-3	OLF operations console, locking mechanism & control circuitry, gas pressurant storage & regulation & control circuitry injection stage separation sys.	OLF operations console in MORL Module 1.	
	(-3) Release locks of MORL Modules 1 & 2	• Electrical signals from OLF Ops. console				5 min	10	719	follow 1.2.4-2			
	(-4) Pressurize bays hub and elevator tubes to 0.5 psi extension press simultaneously	• Remote operation of pressure valves on storage bottles in bays and hub	2	OLF Console Opr.	E/E & S/M	5 min	10	729	follow 1.2.4-3			
	(-5) Control extension of MORL Module by pressurization and venting.	• Remote control of pressure regulators & vent valves in experiment & hangar bays	2			15 min	30	759	follow 1.2.4-4	Gas pressurant storage and control systems	OLF Operations console in MORL Module 1	
	(-6) Verify full extension of each MORL Module.	• Visual observation of position and pressure indicators.		Console Opr.	E/E & S/M				follow 1.2.4-5			
	(-7) Pressurize hub, bays & elevator tubes to 3.5 psi & verify proper temp. control of those areas.	• Remote control of stored gas pressurants in hub and bay areas.	2			20	40	799	follow 1.2.4-6			
	(-8) Crewmen, in spacesuits & oxygen masks, transfer through MORL airlock elevator tubes & hub into experiment bay & install locking mechanisms & permanent seals.	• Manual operations including seal & locking ring installations inspections, etc.	3	Mech. & Console Opr	LS/ECS & S/M (E/E at Console)	45 min	135	934	follow 1.2.4-7	Crew oxygen masks & "carry-around" bottles also O_2 supply lines & outlets in hub & bays; hard tools & small power wrenches & inspection equip.	MORL-to-elevator tube airlock, hub section & experiment bay.	Egress operation through MORL airlock to "shirtsleeve/oxygen mask" environment. Spacesuits are worn without helmets or gloves only for emergency during this work. Helmets & gloves must be immediately available. NOTE: Crewmen transferring from 7.0 psi "shirtsleeve" to 3.5 psi "shirtsleeve-oxygen mask" environment must don oxygen masks and prebreathe 100% O_2 at least 30 min. before transfer into 3.5 psi areas to prevent bends.
	(-9) Crewmen install permanent seal & structural supports on exp. bay elevator tube.	• Manual operations	3	Struct. & Console Opr.	LS/ECS & S/M (E/E at Console)	40 min	120	1054	follow 1.2.4-8	MORL-to-elevator tube airlock (preferably 3-man capacity)	Experiment bay & elevator tube	
	(-10) Crewmen perform cursory inspection of experiment bay for damage in-	• Visual inspection of structures, lines, fittings, hatches, etc.	3	Mech., Struct., & console Opr	LS/ECS & S/M (E/E at Console)	20 min	60	1114	follow 1.2.4-9			

Figure 4.1-11 FUNCTION & TASK ANALYSIS - (Cont.)

MAJOR EVENTS	TASKS		PERSONNEL			TIME				EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
	DESCRIPTION	PROCEDURE	NO. PERSONS	SKILLS REQUIRED	CREW ASSIGNED	ELAPSED	MAN-MINS. PER TASK	ACCUM. MAN-MINUTES	SEQUENCE LIMITATIONS			
1.2.4 (Continued)	(-10) (continued) curred during earth launch injection & MORL extensions. Perform minor repairs as required.											
	(-11) Crewmen transfer thru hub section to hangar bay and install MORL 2 locking mechanisms & permanent seals.	• Manual operations same as for 1.2.4-8	3	Mech. & console Opr.	LS/ECS S/M & (E/E at console)	45 min	135	1249	follow 1.2.4-10	Same as for 1.2.4-8 thru -10 except MORL-to-elevator tube airlock.	Hub sections & hangar bay	
	(-12) Crewmen install permanent seal & structural supports on hangar bay elevator tube.	1. Manual operations	3	Struct. & console Opr.		40 min	120	1369	follow 1.2.4-11		Hangar bay, hub & hangar bay elevator tube.	
	(-13) Crewmen perform cursory inspection of hangar bay & hub section for possible damage incurred during earth launch, injection & MORL extensions. Perform minor repairs as required.	• Visual inspection of structures, lines fittings, hatches, etc.	3	Mech., Struct. & console Opr.	LS/ECS, S/M & (E/E & C/O alternating at console	20 min	60	1429	follow 1.2.4-12			
	(-14) Crewmen transfer to MORL Mod 2, & activate MORL environment control subsystem.	• Pushbutton connection of power to MORL 2 ECS, bus. Pumpdown & then repressurization of airlock & pushbutton activation of ECS.	2	ECS (& console Opr.)		10 min	30	1459	follow 1.2.4-13	Remote activation systems for MORL Mod. 2 & environmental control system.	Hub, hangar bay elevator tube & MORL Module 2 airlock.	Airlock operation at MORL Mod. 2, MORL-to-elevator tube airlock.
	(-15) Confirm operation of MORL Mod. 2 environmental control systems & enter MORL Mod. 2	• Visual observation of instruments & manual operations.	3	ECS & console Opr.	LS/ECS & S/M (C/O at console)	5 min	15	1474	follow 1.2.4-14	Remote ECS and power monitoring instrumentation (MORL Mod. 2)	MORL Mod. 2 airlock & Mod.	Airlock operation * (MORL-to-elevator tube airlock - MORL Mod. 2). *This is continuation of work from airlock in 1.2.4-14.
	(-16) Crewmen check ECS & battery charge condition of MORL Mod. 2	• Visual inspection of instrumentation	3			5 min	15	1489	follow 1.2.4-15	Panel instrumentation (MORL Mod. 2)	MORL Module 2	
	(-17) Full pressurization (7 psi) of elevator tubes & hub areas	• MORL systems are used to pressurize hub & tubes from 3.5 to 7.0 psi. Panel switching & Instrument monitoring required	1	console Opr.	C/O	5 min see remarks	5	1494	follow 1.2.4-14 may be concurrent with 1.2.4-15 & -16	Panel control of of ECS & monitoring instrumentation	Operation at OLF Ops. console in MORL Mod. 1.	Time allowed is merely for initiation. Actual pressurization from pressurants stored in liquid condition will require about 7.6 kw hrs. (With 2 kw available, the time req'd would be ~ 4 hrs.) Console monitoring should be continuous for full 4 hours.
1.2.5 Deployment of antennas and activation of primary communications & tracking aids.	(-1) Crewmen in MORL Module 2 deploy antennas & checkout communication & tracking aids.	• Pushbutton initiation & visual observation of deployment. Comm. Sys. coordinated checkout between earth, OLF & CM.	3	Console Opr's & Observer	LS/ECS & S/M (PCO at CM Console)	15 min	45	1539	follow 1.2.4-16	Antenna deployment & control systems OLF-to-earth Comm. Sys.	MORL Modules 1 & 2 and Apollo Command Module	
	(-2) Repeat above for MORL Module 1. (see sequence limitations)	• Same as 1.2.5-1 except CM is no longer in the loop.	2	Console Opr. & Observer	PCO & C/O	15 min	30	1569	follow 1.2.6-3 (see remarks)			Antennae are not deployed on MORL Module 1 until CM stowage & fairing removal and transfer has been accomplished.
1.2.6 Assembly and deorbiting of injection stage & CM fairing.	(-1) Crewmen in CM shuts down CM and transfers to MORL Module 1	• Pushbutton shutdown, visual inspection & manual transfer thru MORL airlock	1	Console Opr.	PCO	30 min	30	1599	follow 1.2.5-1 (see remarks)	Apollo systems	Apollo Command Module	Airlock operation required, adjustment of atmosphere required NOTE: This position of Major Event 1.2.6 in the total

Figure 4.1-11 FUNCTION & TASK ANALYSIS - (Cont.)

MAJOR EVENTS	TASKS: DESCRIPTION	TASKS: PROCEDURE	PERSONNEL: NO. PERSONS	PERSONNEL: SKILLS REQUIRED	PERSONNEL: CREW ASSIGNED	TIME: ELAPSED	TIME: MAN-MINS. PER TASK	TIME: ACCUM. MAN-MINUTES	TIME: SEQUENCE LIMITATIONS	EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
1.2.6 (Continued)												sequence of operations as shown here is only required if solar panels are used as the primary electrical power source. This is to prevent damage to the panels after they are deployed.
	(-2) Transfer of CM and attached fairing to stowage position on MORL Module.	• Manipulation of MORL stowage arms.	3	Mech. & Console	FCO, E/E (& C/O of console)	10 min	30	1629	follow 1.2.6-1	Stowage arms for MORL Mod. 1	MORL Mod. 1	
	(-3) Crewmen from MORL Module 1 exit thru MORL exterior airlock, checkout communications, remove fairing from CM & transport to injection stage at opposite end of OLF.	• Manual operations including donning of spacesuits, egress thru airlock, release of fairing & transfer to injection stage using AMUs.	3			60 min	180	1809	follow 1.2.6-2	2 AMUs and possibly some hand tools for releasing CM fairing, releasing injection stage & attaching CM to injection stage TV monitoring equip.	MORL Module 1, exterior airlock & exterior of OLF	External airlock operation required from MORL Module 1. NOTE: Crewmen participating in this extravehicular activity must don oxygen masks and prebreath 100% oxygen prior to exit operations. May start this during 1.2.6-2.
	(-4) Attach fairing to forward end of injection stage & separate from OLF.	• Manual release & rotation of injection stage (still tethered or attached to OLF) & attachment of fairing. AMUs are used to transport injection stage & fairing to safe distance from OLF. Radio controlled C/O of assembly accomplished while crew are available in exterior environment	3	General skills required for EVA & console Opr.	E/E & C/O (FCO at console)	40 min	120	1929	follow 1.2.6-3		Exterior of OLF & OLF opr. console in MORL Mod. 1	
	(-5) Crewmen make visual inspection of OLF attitude control & stabilization thrusters & return to MORL Module 1.	• Visual inspections, AMU's used for transfer, manual operations in airlock and entrance to MORL Mod. 1, suit removal and checkout also required.	3			60 min.	180	2109	This can be done anytime prior to 1.2.7		OLF exterior, MORL Module 1 airlock & OLF opr. console in MORL Mod. 1	Ingress through MORL Mod. 1 external airlock.
	(-6) Deorbit of injection stage & CM fairing	• Radio control of injection stage thru IU and coordination with earth stations for positions, etc.	2	Flight Control & Observer	FCO & C/O	80 min	160	2269	follow 1.2.6-4	Radio control equip.	OLF operations console in MORL Module 1.	This time is estimated on the basis of 85% of one orbital period.
1.2.7 Activation & Checkout of all OLF	(-1) Activation of primary reaction control & stabilization system.	• Pushbutton control of pressurization of reaction control syst. • Remote operation & checkout of thruster operations. Direct observation and instrumentation evaluation.	2	Flight Control	FCO & C/O	10 min	20	2289	follow 1.2.6-5	Reaction control & stabilization system with control circuitry, instrumentation, & control mechanisms.	OLF operations console in MORL Module 1.	
		• Interrogation of computer, coordination with earth & command proper orientation of OLF as required (computer inputs).				20 min	40	2329				
	(-2) Checkout of OLF checkout systems.	• Console operation	2	Checkout Opr.	C/O & E/E	15 min	30	2359	follow 1.2.7-1	OLF checkout equip. & display	Checkout & OLF consoles in MORL Module 1.	

Figure 4.1-11 FUNCTION & TASK ANALYSIS - (Cont.)

MAJOR EVENTS	TASKS: DESCRIPTION	TASKS: PROCEDURE	PERSONNEL: NO. PERSONS	PERSONNEL: SKILLS REQUIRED	PERSONNEL: CREW ASSIGNED	TIME: ELAPSED	TIME: MAN-MINS. PER TASK	TIME: ACCUM. MAN-MINUTES	TIME: SEQUENCE LIMITATIONS	EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
1.2.7 (Continued)	(-3) Crewmen station themselves at assigned checkout stations.	• Two crewmen to hub, 2 men in MORL Mod. 1 & 1 man in MORL Mod. 2	2 see remarks	General	FCO & S/M	5 Min.	10	2369	Follow 1.2.7 can be concurrent with 1.2.7-2	No special equip.	MORL Modules 1 & 2 hub.	One man from each MORL Module transfers in shirtsleeve environment to hub.
	(-4) Checkout environmental control & life support systems.	• Check atmosphere supply & pressurization systems supplies, regulation & control, & displays.	5	Console Opr. & General Checkout Skills. (Primarily ECS)	Full Crew	15 Min.	75	2444	Follow 1.2.7-3	ECS instrumentation & display		One crewman reads off checklist, one crewman in each MORL Module and two in hub makes checks.
		• Check performance of airlock pumping systems, spacesuit outlets, etc.	5			80 Min	400	2844		Checkout & display equipment including flowmeters, temperature, humidity & contaminant sensing devices, valves, plumbing, display gauges, etc.	MORL Modules 1 & 2 hub areas & bays	Airlocks are used in hub areas for entrance into bays for checking suit connections, gas pressure storage, etc. Crewman enter bays in oxygen masks; hence, must prebreathe 100% oxygen for at least 30 minutes prior to entry.
		• Make similar checks of atmospheric control & purification systems	5			15 Min	75	2919				
		• Check compartment conditioning systems (including radiator systems) for outputs, flow rates, temperatures, humidity, controls, display & general performance.	5			30 Min	150	3069	Follow 1.2.7-3			
		• Check water management system, quantities, temperatures, flow rates, sensor operation controls displays & performance	3	Console Opr. & Observers (primarily ECS)	Crewmen in MORL Mods. 1 & 2 C/O LS/ECS & E/E	15 Min (see remarks)	(see remarks)	0 (see remarks)	Follow 1.2.7-3 concurrent with previous parts of this task		MORL Modules 1 & 2	This is accomplished during time that 2 men are returning to hub through airlocks and time (including "man-mins per task") is accounted for in preceding part of this task.
		• Check waste management system, valve operations, dehydration temperatures & pressures, controls, displays & performance.										
	(-5) Checkout electrical power system	• Check temperatures & pressures of isotope, heat exchangers, loops, radiator & CHU.	3			15 Min	45	3114	Follow 1.2.6	Nuclear isotope power system, power regulation & distribution equip., battery charging system & switching circuitry.	MORL Modules 1 & 2	
		• Check switching & distribution circuitry & overall system performance.									MORL Modules 1 & 2 hub	
		• Check radiation levels at various locations.										
	(-6) Checkout communications, telemetry & data management systems.	• Check all modes of operation of all communication links (links for EVA have been checked in 1.2.6-3)								Communications equip. necessary for voice TV & data transmission within the OLF; voice, TV, tracking & data transmission between OLF & earth; & voice & TV transmission for EVA.	MORL Modules 1 & 2 and hub areas. Ground coordination also required.	

Figure 4.1-11 FUNCTION & TASK ANALYSIS - (Cont.)

MAJOR EVENTS	TASKS		PERSONNEL			TIME				EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
	DESCRIPTION	PROCEDURE	NO. PERSONS	SKILLS REQUIRED	CREW ASSIGNED	ELAPSED	MAN-MINS. PER TASK	ACCUM. MAN-MINUTES	SEQUENCE LIMITATIONS			
...7 Continued		. Check telemetry conversion & transmission digital command signal reception & reaction, operation of tape recorders, TV cameras, transmitters & receivers, acquisition beacon & radar tranponder data processing & computer systems.	5	Console opr. & general checkout skills (primarily elec.)	Full crew	60 Min.	300	3414	Follow 1.2.7-5			
	(-7) Checkout orbit control & stabilization systems.	. Check operation of sensors, gyros, redundant circuitry thrusters, controls & displays.	3	Flight control & observer	Crewmen in MORL Mod. 1 & 2	30 Min.	90	3504	Follow 1.2.6	Stated in 1.2.7-1	MORL Modules 1 & 2	
		. Check systems operational capability to maintain orientation & be manually controlled in required maneuvers.			PCO C/O & E/E	40 Min	120	3624				
	(-8) Checkout structure & mechanical systems.	. Check basic structures for damage during launch and/or erection, security of mountings of all equip., proper sealing of all joints & operation of hatches, proper cabling, plbg. etc.	5	Console Opr. & general checkout skills (primarily struct. & mech.)	Full Crew	90 Min.	450	4074		Inspection equip., including lights, leak detection equip. etc.	MORL Modules 1 & 2, hub & bays.	Internal structures only: however, airlock operations req'd for entry into experiment & hangar bays. Crews entering bays do so in oxygen masks after 30 min. of prebreathing 100% oxygen. This time need not be divided equally among crews.
		. Install and checkout equipment in experiment bay, hangar bay, elevator tubes & hub areas such as hatch operating mechanisms, elevator systems, equipment & cargo handling equipment, etc.	2	Mech. & Struct.	S/M & E/E	240 Min.	480	4554	follow 1.2.7-6	Hangar exterior hatch operating mechanisms, tracks, etc., elevators & assoc. transfer mechanisms, cargo & equip. handling conveyors or cranes, power & hand tools.	Hub, bays and elevator tubes.	Airlock operations required for crewmen to return from hangar & experiment bays into hub section.
		. Crewmen egress to exterior, open docking port covers inspect docking mechanisms (& remove any structural supports required during launch. Open servicing boom & umbilical covers & inspect. AMUs used for transport. Replace covers for meteoroid protection & return to OLF. interior. Suit donning, removal & checkout & reservicing req'd.	3	console opr., general EVA skills & mech. & struct.	PCO, C/O (LS/ECS & E/E alt. at console)	180 min	540	5094		2 AMUs, simple hand tools (screw driver & pliers) & inspection equipment.	Hub section airlock & exterior of OLF.	Exterior airlock operations required for both egress and ingress operations. Crewmen prebreathe 100% oxygen at least 30 minutes before egress. Airlock at hub would be convenient for this use.
		. Check operation of centrifuges (simultaneous operation of two systems.	[illegible]	console opr. & general crew skills	PCO, LS/ECS & E/E	50 min	150	[illegible]		Centrifuges & control and monitoring systems.	MORL Modules 1 & 2 centrifuge areas & console	
	(-9) Checkout audio & visual alarm systems	. Systems activation from various locations in the OLF & observation of systems performance.	[illegible]	console opr. & observers	PCO LS ECS & E E	15 min	45	[illegible]	follow [illegible]	Alarm system including buzzers or bells, lights circuitry etc.	MORL Modules 1 & 2 & hub section.	

Figure 4.1-11 FUNCTION & TASK ANALYSIS - (Cont.)

MAJOR EVENTS	TASKS		PERSONNEL			TIME				EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
	DESCRIPTION	PROCEDURE	NO. PERSONS	SKILLS REQUIRED	CREW ASSIGNED	ELAPSED	MAN-MINS. PER TASK	ACCUM. MAN-MINUTES	SEQUENCE LIMITATIONS			
1.2.7 (Continued)	(-10) Checkout maintenance & repair equipment & facilities	. Operation of power tools calibration equip. & hand tools, Visual inspection of facilities	2	primarily mech.	S/M & E/E	30 Min.	60	5379	Follow 1.2.7-5	Little more than the M&R tools & equip. themselves with calibration gauges	MORL Module 2 work shop area.	
1.2.8 Repairs	(-1) Repair malfunctioning or damaged systems as determined nec. in systems check-out & inspection.	. Manual operations replacing spares minor disassembly & reassembly, recalibrations etc.	4	Mech. Struct. elec. SCS console opr.	Full crew participates	240 Min.	960	6339	follow 1.2.7	Small shop area for minor disassembly-type repairs, hand tools & simple mobile power tools.	Wherever repair is required.	

ROUTINE OPERATIONS AWAITING ORBITAL LAUNCH OPERATIONS

Figure 4.1-11 FUNCTION & TASK ANALYSIS -(Cont.)

established in the subsequent crew utilization timeline analysis. Skills and crew coding are also discussed in that analysis.

Columns 7, 8, 9, and 10 all present time and sequence information. Column 7 gives an estimate of the amount of elapsed time required to accomplish the task or series of tasks. This elapsed time, multiplied by the number of persons involved in the task, gives the man-minutes per task (or per series of tasks where the individual tasks are almost inseparable for time estimating purposes) in Column 8. Column 9 presents the running total of man-minutes required to accomplish the work and Column 10 indicates the sequence of the task, inasmuch as the task listings are not all chronological. Column 11 is a general listing of equipment required to perform the tasks and is used to identify major systems required. Obviously, many of the tasks required in the operation are dependent upon the equipment included in the design, but it is necessary to account for all systems requirements to be sure that overall systems design is capable of supporting the specified operations. Column 12 lists the location of the tasks, primarily for use in the crew scheduling analysis. Any deviations in the column entrees from what is described above, in addition to clarifications or notations, are all listed in Column 13 under REMARKS.

It should be noted that several iterations of this analysis, as well as the event-logic and crew utilization, were required to provide what is now felt to be a reasonable plan and time estimate for the OLF launch, orbital assembly and checkout phase of the OLF operations. Detailed descriptions of the tasks and procedures required to accomplish the OLF operations major events for this phase are given in the function and task analysis sheets of Figure 4.1-11. Summation of the work-time requirements for crew work during launch, orbital assembly and checkout of the OLF provides a total man-minutes requirement of 6339 man-minutes or about 106 man-hours. A summary of the work requirements by skill is presented in Figure 4.1-12 below:

FIGURE 4.1-12

OLF LAUNCH, ORBITAL ASSEMBLY & CHECKOUT WORK & SKILL REQUIREMENTS SUMMARY

Skill *	Work-Time Man-Mins.	Requirements Man-Hrs.
Flight Command	754	12.57
Console Operation & Checkout	1210**	20.16**
Environmental Control System	850	14.17
Mechanical	1170	19.50
Structural	950	15.83
Electronic/Electrical	510	8.50
General	895	14.92
Total	6339	105.65

FIGURE 4.1-12 Continued

OLF LAUNCH, ORBITAL ASSEMBLY & CHECKOUT WORK & SKILL REQUIREMENTS SUMMARY

* Assumes that each crew member is capable of more than one skill.

** These times are strictly console operator skill time required as part of the established task work and do not include routine console monitoring between tasks, during eating, sleeping, etc.

The total work-time requirements stated in the table above can be considered the minimum work requirement estimates based strictly on the function and task analysis without crew utilization considerations. Much of the work-time indicated requires only a "technician-level" of skill, a level of proficiency that could conceivably be shared by several crewmen. Most of the flight command operations, however, and the checkout of the checkout systems, does require a higher level of skill in those particular fields. A more detailed discussion of skills is presented in Para. 4.3, Crew Requirements. Of the total work time, 1520 man-minutes or about 25.4 man-hours of work is required outside of the shirtsleeve environment, for a total elapsed time of about 12.7 hours each for two men. These times include three excursions into what is referred to in this study as a "shirtsleeve/oxygen-mask" environment (3.5 psi environment requiring oxygen masks -- primary environment of experiment and hangar bays) for a total elapsed time of 7 hours and two extravehicular excursions of a total elapsed time of 5.7 hours. In both the extravehicular and shirtsleeve/oxygen mask work, two men are involved in the actual work with one man monitoring at the console. The console operation time is not included in the 1520 man-minutes stated above. The extravehicular activity (EVA) times include the time for donning and checkout of the spacesuits, airlock egress and ingress operations, and suit removal checkout and servicing, as well as the EVA times themselves. The times assumed for these operations are shown in Figure 4.1-13 below:

FIGURE 4.1-13

AIRLOCK & SPACESUIT DONNING, REMOVAL & CHECKOUT OPERATIONAL TIMES

Don & checkout spacesuits	10 minutes
Egress thru airlock (conserving atmosphere)	16 minutes
Ingress thru airlock	6 minutes
Spacesuit removal, checkout & servicing	20 minutes

Descriptions of the tasks which require the extravehicular and shirtsleeve/oxygen mask activities, are presented under major events 1.2.4, 1.2.6, and 1.2.7 of the function and task analysis sheets of Figure 4.1-11.

To time-phase the OLF launch, orbital assembly, and checkout operations, it was first necessary to schedule the tasks by crew members and integrate them into "eat-work'sleep" routines for the crew. The nature of the work in this phase, as determined in the task analysis, indicated a distinct desirability for a 5-man crew to accomplish the assembly and checkout work.

From the study of routine station keeping activities and maintenance and repair analysis, it was determined that a minimum OLF crew of four men could adequately do that job. This size crew, with the addition of one man, preferably with checkout skills, was therefore used in the crew utilization timeline analysis for this phase. The timeline itself is shown in Figure 4.3-1 of Paragraph 4.3 and is discussed in more detail in that section. However, because of the relatively few man-hours of work required for this phase of the operation and consequently an expected short duration of elapsed time required, it was felt that the crew could be put on a "high activity" schedule for this period, sleeping only 3.5 hours of each 12-hour period and using reduced relaxation and leisure time allocations. The total elapsed time required to accomplish this phase, using the high-activity schedule shown in Figure 4.3-1, was determined to be approximately 55 hours. Detailed summaries of crew times in various activities are presented and discussed in the crew requirements analysis of Section 4.3. This 55-hour time period, as previously mentioned, assumes a nominal operation in which no failures, which would require alternate action, would be encountered. The nominal operation, however, does allow 4 hours of elapsed time in which repairs of malfunctions, which have not instigated alternate action, can be made.

If failures of significance were encountered during the launch, assembly and checkout phase, alternate actions as those indicated in the event logic network of Figure 4.1-11 may be required. These alternate actions would cause delays in the operation; therefore, allowances must be made for such occurences. As discussed before, an analysis of the probability of failure during each of the operational events, using a computer program, would provide an estimate of the average delay time that could be expected within the accuracy and applicability of the statistical data used in the program. Such a study is not warranted at this level of operational analysis, particularly inasmuch as the nominal time required for this phase is only 55 hours, which is under 2 percent of the total time required for the orbital launch operations. However, from the standpoint of time phasing the overall operations, it is desirable to have some idea when the latest OLF Earth launching could occur without affecting the orbital launch operations. For an analysis of this situation the OLF launch, assembly, and checkout operations constraints were evaluated in conjunction with Earth launching operations constraints as they apply to the entire orbital launch operations.

As an extreme case, and in lieu of the unwarranted failure probability analysis mentioned above, it is assumed that the first OLF is launched, assembled and checked out and experiences a major failure just at the end of this 55-hour period. The backup OLF is called up and proceeds through its launch, assembly and checkout in a nominal fashion. On the basis of this, the first OLF should be launched no later than 110 hours prior to the initiation of the orbital launch operations.

From consideration of Earth launch operations in support of the orbital launch operations and the requirement for in-orbit preparation of checkout and launch equipment on board the OLF (from Lockheed SCALE study of Reference 3) at T-147 days, it was found that the latest date that the first OLF could possibly be launched would be at T-147 days minus 110 hours (4.5 days) or T-151.5 days, and the backup OLF could be launched as late as T-149.5 days. Both Saturn V launch pads could be used on those launch dates and still be available for use in the spacecraft launchings as planned. For all practical purposes, then, the latest possible dates for Earth launch of the OLF are at T-152 and T-150 days for the first and alternate OLFs respectively. This time phasing with respect to OLO assumes that the OLF, which is launched from Earth and checked out in orbit, is an operational facility, i. e., no further RDT&E must be performed on the OLF in orbit. This merely establishes estimates of latest possible dates for OLF Earth launch. In consideration of OLF RDT&E requirements, as discussed in Paragraph 7.1, it appears that the OLF Earth launch date must be considerably earlier to permit orbit qualification of the OLF and OLO.

4.1.3.3 Systems Requirements -- OLF Launch, Assembly, & Checkout. - Actually, there are very few systems or pieces of equipment on board the OLF for which this phase of operation can claim exclusive authorship of the requirements. Column 11 of the function & task analysis sheets of Figure 4.1-11 lists the various general systems or equipment required in the proposed operations. However, many are prescribed primarily by the basic Earth launch packaging and orbital operations requirements. The particular method of accomplishing the launch, assembly and checkout does stipulate some special systems requirements such as:

a. Flight control linkage between Command Module and S-II stage of the Earth launch vehicle.

b. Remote control for activation of MORL ECS and monitoring instrumentation from MORL airlocks.

c. Stowage arms near the docking ports of MORLs to handle CM and injection stage, in addition to possible use in logistics vehicle manipulation.

d. Oxygen masks, mobile oxygen supplies (walk-around bottles), and oxygen supply outlets throughout the hub and bay areas.

e. Hand tools, both manual and powered, and basic inspection equipment, lights, leak detection equipment, etc.

f. TV monitoring cameras and viewing ports, primarily in MORLs and possibly in hub for viewing EVA and systems deployment.

g. At least 2 AMUs and reserve units for EVA, particularly in handling large equipment such as CM fairing, injection stage, etc.

h. Radio control link for flying and deorbiting injection stage and CM fairing.

i. Emergency alarm system that can be initiated from any major area in the OLF.

The systems analysis for this portion of the study consisted primarily of the identification of systems or equipment required in performing the established tasks and evaluation of those systems only to the point of assuring operational compatibility. Detailed analysis of each system is discussed in Paragraph 5.4.

4.1.3.4 Routine Operations -- OLF Operations During and After OLO. - As discussed earlier in the report, because of the study interface which existed between the OLO studies associated contractors in the actual orbital launch operations phase, the OLF study was delegated the responsibility of studying the routine station keeping and logistics operations required during the orbital launch operations. These operations of the OLF are herein referred to as routine OLF operations and are divided into station operations, personnel operations, and maintenance operations. These routine operations apply equally during both phase three -- orbital launch operations and phase four -- scientific and R&D operations.

FIGURE 4.1-14 -- OLF ROUTINE OPERATIONS

Station Operations

1.0 Systems Monitoring

2.0 Navigation, Attitude Corrections & Orbital Maneuvers

3.0 Logistics Operations of the OLF

4.0 General Station Housekeeping

5.0 Artificial Gravity Operation (Alternate Capability)

Personnel Operations

1.0 Crew Condition Assessment

2.0 Crew Training & Emergency Drills

3.0 Personal Care

4.0 Relaxation & Conditioning

5.0 Nutrition

6.0 Sleep

Maintenance Operations

Defined in Section 4.2.

Function and task analyses of the station and personnel operations included in Figure 4.1-14 were performed in this part of the overall analysis. The applicable detailed analysis sheets are presented in Figure 4.1-15. Inasmuch as the manhour requirements for personnel operations are dependent upon the crew size, those requirements are discussed in Paragraph 4.3, Crew Requirements. The maintenance operations requirements are also discussed in another paragraph, Paragraph 4.2, hence are not repeated here. The manpower and skill requirements for station operations only are summarized in Figure 4.1-16.

MAJOR EVENTS	TASKS: DESCRIPTION	TASKS: PROCEDURE	PERSONNEL: NO. PERSONS	PERSONNEL: SKILLS REQUIRED	PERSONNEL: CREW ASSIGNED	TIME: ELAPSED	TIME: MAN-MINS. PER TASK	TIME: ACCUM. MAN-MINUTES	TIME: SEQUENCE LIMITATIONS	EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
STATION OPERATIONS 1. Systems Monitoring at OLP Console	(-1) General observation of console instrumentation.	. Periodic checklist guided instrumentation observations.								OLP console & systems performance displays, communication & data transmission systems. Typewriter.	OLP console in MORL Module 1	
	(-2) Direction of routine communications & data transmission to earth.	. Once per orbit checkin with earth based comm. stations & data relay.	1	Console operations	Crew alternates	1440 mins/day	1440/day		continuous			
	(-3) Initiate malfunction alert and/or emergency alarm	. Push button initiation										
	(-4) Maintain station log	. Typewritten entrees										
2. Navigation Attitude Correction & Orbital Maneuvers	(-1) Take position & attitude readings	. Automatic & Manual operations								Attitude stabilization & control system. Manual backup control RCS system for orbital maneuvers	OLP Console in MORL Module 1	
	(-2) Correct and/or update computer for attitude stabilization.	. Correlate & coordinate pertinent data with ground station & feed new data to computer.	1	Flight Command		30 min/wk	30/wk					
	(-3) Change attitude of OLP as may be required or desired.	. Manual control & possibly feed new data to computer.				60 min/wk	120/wk		as required			
	(-4) Maneuver OLP for necessary orbital corrections or systems separations	. Manual and/or computer control	2			180 min/mo	360/mo					
3. Logistics operations at the OLP.	(-1) Rendezvous & docking direction	. Operation of tracking radar, visual observations & verbal radio directions	2	Flight Command & radar		90 min/90 days	180/90 days		Sequence as shown. However, reloading & earth return may be delayed to a later time	Logistics S/C, Docking & sealing mechanisms, cargo handling, equip. for expeditious unloading if required.	OLP Console in MORL Module 1 & hub section.	. Assumed to be accomplished within one orbital period.
	(-2) Assure positive docking & sealing for shirtsleeve unloading of logistics S/C.	. Indicator observations & Manual operations	2	Mech.		20 min/90 days	60/90 days					
	(-3) Cargo & personnel unloading & reloading for earth return	. Manual operations with possibly some conveyor or handling equipment.	3	General		180 min/90 days	540/90 days					
4. General Station Housekeeping	(-1) Station cleaning	. Vacuum accumulation of debris & dirt Sterilization cleaning of all equipment coming into contact with the human body. . Observation ports & instrumentation cleaning	3	General		240 mins/wk	720/wk		None	Vacuum cleaner & filtering system, sterilization cleaning pads, lint free wipers, laundry facilities	Entire station	. Some station rotation to settle debris & dirt may be advantageous for station cleaning. Use of vacuum tube attachments on shavers, hair clippers, nail cutters, etc. will help minimize debris in the cabin.
	(-2) Clothes cleaning	. Sanitized dry cleaning where applicable & possible regular laundry & dryer utilization	1	General		60 min/wk	60/wk					

Figure 4.1-15 FUNCTION & TASK ANALYSIS - ROUTINE OPERATIONS

MAJOR EVENTS	TASK DESCRIPTION	TASK PROCEDURE	PERSONNEL NO. PERSONS	PERSONNEL SKILLS REQUIRED	PERSONNEL CREW ASSIGNED	TIME ELAPSED	TIME MAN-MINS. PER TASK	TIME ACCUM. MAN-MINUTES	TIME FREQUENCY LIMITATIONS	EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
5. Artificial "g" operation	(-1) Spin-up OLF for artificial gravity	. Systems checkout & initiation of computer controlled RCS to provide proper "g" level	2	Flight Command		90 mins 90 days see remarks	180/90 days		All Systems must be in readiness before either spin-up or spin-down	RCS system & spin stabilization sensing & control system	CLF Console in MORL Module 2	.These times are based upon three operations every 90 days, each requiring about 60 minutes for checking out systems and equipment as well as the actual spin-up or spin-down operation itself.
	(-2) Spin-down OLF for desired zero "g" or non-rotating conditions.	. Systems checkout & initiation of computer controlled RCS for stopping station rotation				90 mins/ 90 days	180/90 days					
PERSONNEL OPERATIONS												
1. Crew condition-assessment	(-1) Routine biomedical tests	. Heart rate & wave form (EKG), blood pressure & body temp.	2	General Medical & psycological		15 min/ wk see remarks	120 min/ wk		As dictated by the tests themselves	EKG preamps & amplifiers sphygmomanometer thermistor, behavioral stimuli & reaction recording equipment	MORL Modules 1 & 2	.These tasks are to be performed for each crew member once per week using a companion crew member for assistance. The man-mins per task times are for a 4-man OLF crew.
	(-2) Routine behavioral tests.	. Sensory & motor tests & psycological testing	2									
2. Crew training & Emergency	(-1) Crew training in station operations & maintenance & repair operations	. Literature reviews, group discussions, operational demonstrations, etc.	4	General		120/min wk	480/wk		None	Systems tech. literature microfilms, viewing equip. etc.	MORL Modules 1 & 2 & hub section	
	(-2) Emergency drills for meeting various emergency situations	. Malfunction simulations & alarm initiation from various areas of the OLF. Remedial action & evacuation drills.	4			120/min wk	480/wk		As dictated by emergency simulated	Alarm system & malfunction simulation systems	Entire Facility	
3. Personal Care	(-1) Personal cleansing	. Hands & face washing at least 5 times per day & bathe once per wk.								Sponge cloths & zero "g" showers.	MORL Modules 1 & 2	.Times indicated were times mutually agreed upon by associated OLO contractors.
	(-2) Dental & oral hygiene	.Normal tooth brushing twice per day with mouth kept firmly closed		General						Tooth brushes & paste		
	(-3) Shaving, hair cutting & nail cutting	. Shaving daily, nail cutting weekly and hair cutting at least twice per month	4			90 min/ day	360/day		Normal	Vacuum attachment equipped shavers, hair clippers & nail clippers		
	(-4) Waste elimination	. Urination several times daily & defacation once per day								Collection & waste processing systems		
	(-5) Medical Care	. First aid operation with one crewmember capable of emergency minor surgery, i.e., appendectomy		First Aid & one semi-skilled surgeon						Gen'l first aid equipment & sufficient surgical equip. to permit minor surgery		
4. Relaxation & Conditioning	(-1) Recreation	. Generally activities different than daily routines, music, art, hobbies, games, movies, TV, etc.	4	General		120 mins/ day	480/day			Movie equip., literature, high-fi tape recorders, TV games, art mat'ls, ect.	Primarily MORL Modules 1 & 2	.Times indicated were times mutually agreed upon by associated OLO contractors
	(-2) Exercise	. Dynamic tension & some active exercises								Dynamic tension type equip., padded area in bay for active exercising 2 centrifuges, one in each MORL		
	(-3) Gravity conditioning	. Use of centrifuge										

Figure 4.1-15 FUNCTION & TASK ANALYSIS - ROUTINE OPERATIONS - (Cont.)

MAJOR EVENTS	TASKS		PERSONNEL			TIME				EQUIPMENT REQUIRED	LOCATION OF TASK	REMARKS
	DESCRIPTION	PROCEDURE	NO. PERSONS	SKILLS REQUIRED	CREW ASSIGNED	ELAPSED	MAN-MINS. PER TASK	ACCUM. MAN-MINUTES	SEQUENCE LIMITATIONS			
5. Nutrition	(-1) Food preparation	. Rehydration of dehydrated foods primarily	4	General		150 mins/day	600/day			Water source & temp. control. Food storage. dining area, dry waste storage & water recovery sys.	MORL Modules 1 & 2 with limited supply in hub section	.At this time dehydrated foods are considered for this application .Times shown are times mutually agreed upon by associated OLO contractors.
	(-2) Eating	. Direct consumption from packages in which they are carried & prepared										
	(-3) Cleanup	. Collection of waste foods in used food containers, dried foods to storage, wet foods for recovery of water										
6. Sleep	(-1) Preparation, sleep, wake & dress	. Change clothes, stow soiled clothes, sleep, awake & don clothes	4	General		480 mins/day	1920/day			Sleeping compartment & bed or hammocks	MORL Modules 1 & 2	

Figure 4.1-15 FUNCTION & TASK ANALYSIS - ROUTINE OPERATIONS - (Cont.)

FIGURE 4.1-16

OLF MANHOURS & SKILL REQUIREMENTS FOR ROUTINE STATION OPERATION

Skills	Man-hours/90 Days
Console Operations	2160
Flight Command	59
Mechanical	1
General	176
Total	2396

The "console operation" referred to here is routine-monitoring-type of console operation, as opposed to the active console operation required in the launch, assembly, and checkout operations. Although this routine monitoring is required 24 hours per day, it is not considered a fully-alert-type operation, i. e., the crew member may do other minor activity during this time as long as he remains within immediate access of the panel and makes periodic assessment of the panel instrumentation. Routine "flight command" operations are primarily navigation and attitude or orbit corrections. "Mechanical" work here is associated with the locking and sealing operations in the docking of logistics craft to the OLF. The "general" category of skills primarily includes general housekeeping and cargo handling. Some of the general skill requirements imposed by the routine personnel operations include those basic skills required to eat, sleep, move about, and perform other personal duties in zero or artificial gravity conditions, as well as first aid and basic medical know-how. It probably will be desirable to have at least one crew member trained to handle minor dental or surgical emergencies, such as tooth extractions or even an appendectomy.

Figures 4.1-17 and 4.1-18 summarize basic man-hour data from the function and task analysis and the separate maintenance analysis to provide a composite look at the OLF routine operations requirements. Inasmuch as the maintenance operations data shown in these figures are for the OLF proper, the totals represent only that required for the OLF itself. This was purposely summarized in this manner to provide the base requirement from which applications may be extended to R&D and scientific operations on board the OLF as well as the orbital launch operations application.

Figure 4.1-19 further summarizes the total man-hour requirements for OLF routine operations for the assumed 4-man or 5-man crew and includes OLO integrated maintenance required on the OLF. The data in Figure 4.1-19 was accumulated on a yearly basis because of some scheduled maintenance which is only required yearly. Obviously, then, the "daily-average-per man" figures are meaningless except to get a general idea of the relative manpower utilization between the assumed 4-man and 5-man crews. These requirements are discussed further in connection with actual crew requirements in Paragraph 4.3.

MAJOR ROUTINE EVENTS	DAILY	WEEKLY	MONTHLY	90-DAYS	YEARLY
STATION OPERATIONS:					
1. Systems Monitoring at OLF Console	24.00				
2. Navigation, Attitude Corrections & Orbital Maneuvers		2.50	6.00		
3. Logistics Operations at the OLF				13.00	
4. General Station Housekeeping		13.00			
5. Artificial-g Operation					
SUBTOTAL	24.00	15.50	6.00	19.00	
PERSONNEL OPERATIONS:					
1. Crew Condition Assessment		6.00			
2. Crew Training & Emergency Drills		16.00			
3. Personal Care	6.00				
4. Relaxation & Conditioning	8.00				
5. Nutrition	10.00				
6. Sleep	32.00				
SUBTOTAL	56.00	22.00			
MAINTENANCE OPERATIONS:					
1. Scheduled	2.08	4.08	14.50	15.17	16.00
2. Unscheduled	* 0.13				
SUBTOTAL	2.21	4.08	14.50	15.17	16.00
TOTAL	82.21	41.58	20.50	34.17	16.00
YEARLY TOTAL	30,007	2,162	246.00	139.00	16.00
* Average based on MTBF calculations.	Daily average per man = 22.3 hrs.			Daily Average	89.23

Figure 4.1-17 SUMMARY OF MANHOUR REQUIREMENTS - 4 MAN CREW

MAJOR ROUTINE EVENTS	DAILY	WEEKLY	MONTHLY	90-DAYS	YEARLY
STATION OPERATIONS:					
1. Systems Monitoring at OLF Console	24.00				
2. Navigation, Attitude Corrections & Orbital Maneuvers		2.50	6.00		
3. Logistics Operations at the OLF				13.00	
4. General Station Housekeeping		13.00			
5. Artificial-g Operation				6.00	
SUBTOTAL	24.00	15.50	6.00	19.00	
PERSONNEL OPERATIONS:					
1. Crew Condition Assessment		7.50			
2. Crew Training & Emergency Drills		20.00			
3. Personal Care	7.50				
4. Relaxation & Conditioning	10.00				
5. Nutrition	12.50				
6. Sleep	40.00				
SUBTOTAL	70.00	27.50			
MAINTENANCE OPERATIONS:					
1. Scheduled	2.08	4.08	14.50	15.17	16.00
2. Unscheduled	* 0.13				
SUBTOTAL	2.21	4.08	14.50	15.17	16.00
TOTAL	96.21	47.08	20.50	34.17	16.00
YEARLY TOTAL	35,117	2,448	246	139	16.00

* Average based on MTBF calcuations. Daily average per man 20.8 hrs. Daily Average 104.02

Figure 4.1-18 SUMMARY OF MANHOUR REQUIREMENTS - 5 MAN CREW

FIGURE 4.1-19 OLF ROUTINE OPERATIONS MAN-HOUR REQUIREMENTS SUMMARY

	Manhours per Year	
	4-Man Crew	5-Man Crew
Station Operations	9,715	9,715
Personnel Operations	21,584	26,980
Maintenance Operations (OLF Proper)	1,271	1,271
TOTAL OLF PROPER	32,570	37,966
DAILY AVERAGE PER MAN	22.31 hrs/man/day	20.80 hrs/man/day
Other OLO Maintenance	558	558
TOTAL OLF ROUTINE OPERATIONS WITH INTEGRATED OLO MAINTENANCE	33,128	38,524
DAILY AVERAGE PER MAN	22.69 hrs/man/day	21.11 hrs/man/day

4.2 MAINTENANCE PLAN

4.2.1 Approach. - The major objective of the Orbital Launch Facility Study is to produce a conceptual design of an initial OLF capable of supporting a manned Mars or Venus flyby mission. The extended period of operation for the OLF will require continuous maintenance and logistic support to assure a high probability of mission success.

This maintenance plan for the OLF is intended to present the overall concept under which maintenance activities are conducted, and serves as a framework on which the support activities of equipment, spares, technical data, and training are planned. A maintenance analysis of the OLF systems was performed to identify the maintenance requirements, and this data was then integrated with other AOLO systems data which was developed independently by LTV and Lockheed and furnished to Boeing. The assumptions and guidelines on which the analysis is based are presented, typical maintenance activities are summarized, the OLF subsystems which were analyzed are identified, and the resulting data is summarized and tabulated.

The basic concept of maintenance for the OLF limits fault correction to replacement of components, with a minimum amount of module repair being performed in orbit. This concept is based on the assumption that the checkout equipment and launch equipment for the mission vehicle will generally be capable of isolating faults to the replaceable components level with a minimum of additional maintenance equipment required. Future detailed analyses of a final configuration would be required to determine whether a substantial mass reduction could be achieved by providing an increased repair capability through the use of additional equipment, spares, and manpower to repair modules rather than replacing them. The limited scope of this OLF study precludes a detailed analysis at this time.

Proper performance of a maintenance analysis requires that certain assumptions and guidelines be established to ensure uniformity of effort. Those used in this analysis include the following:

a. The system checkout equipment, together with available instrumentation and the effective use of available test points will provide the capability to isolate faults to the replaceable component level.

b. Repair of subsystem malfunctions will be limited to replacement of the lowest replaceable component (i. e., a component which may be removed by unplugging or with simple tools). A limited amount of other repair may be permitted when it would prevent a mission failure and the capability exists to perform the repair.

c. Redundancy will be built into the systems to protect against those crew safety or mission critical failures which could not be repaired within the allowable system downtime (i. e., system is designed such that no single equipment failure will cause mission failure).

d. Acoustic or visual warning devices will be provided to give immediate warning of the failure of critical components.

e. Shut-off type quick disconnects will be used on all replaceable components.

f. The design approach used will ensure negligible failure rates for tubing connectors (electrical, fluid, gaseous), wiring, and clamps.

g. Captive bolts, screws, and nuts will be used so that loosening of these items will not result in a loose floating object.

h. Interconnecting wiring which might be expected to require repair or modification will use wire wrap techniques for high reliability and easily repairable connections which will eliminate the need for soldering and its associated problems.

i. Equipment will be designed for maximum ease-of-maintenance with the available personnel skill levels and in the expected space environment.

j. Replaceable components can generally be replaced without the use of special tools.

k. The maintenance personnel and necessary spares will be located in the MORL in which the failure occurred.

l. Adequate lighting capability will be provided for both external and internal maintenance.

m. Maintenance inside 3.5 psia hangar bays will require wearing an oxygen mask. Sufficient outlets are provided to enable any area of the hangar bays to be reached for maintenance.

n. Pressurized spacesuit activity requires 35% more time than the same activity in a shirtsleeve environment on the ground.

o. Work endurance in a pressurized spacesuit will be an average of 4 hours/day with a maximum of 8 hours.

p. Extravehicular activity will require about 50 minutes for egress and ingress of vehicle (25 minutes for each).

q. Thermal or micrometeoroid protection for personnel performing extravehicular activity (may be spacesuit protective garments) will be provided.

r. On-board spares will be included to provide a 99% probability that the integrated OLF spare will be available.

s. The initial OLF launch will include spares and expendables for 135 days.

t. Resupply missions will be launched every 90 days for crew recycling and to replenish spares and expendables.

u. Replenishment of cryogenic or gaseous fluids at resupply intervals will be accomplished by pressure transfer to the OLF through umbilical connections between the OLF and the resupply vehicle.

v. The Apollo logistics vehicles will be kept fully operational at all times, and will be recycled to Earth every six months by interchanging with the logistic vehicles.

Maintenance is defined as all the actions necessary to maintain the OLF subsystems in, or restore them to, a serviceable or operating condition. This includes both scheduled and unscheduled maintenance activities. Typical activities considered in each of these categories are as follows:

A. SCHEDULED MAINTENANCE

1. Routine inspection, servicing, and preventive maintenance operations (e. g., servicing batteries; replenishing cryogenics, gases, water, cooling fluids, propellants; replacement of filters, chemicals,wicking; cleaning functions, etc.).

2. Replacement of components due to normal wearout or scheduled replacement (e. g., batteries, reaction control engines, etc.).

B. UNSCHEDULED MAINTENANCE

1. Replacement of components because of random failures.

2. Recalibration or adjustments required to bring component operation back within required tolerance.

3. Repair of damage resulting from micrometeoroid impacts, docking operations, unanticipated human errors during maintenance, or handling of equipment.

4. Modifications to equipment to incorporate improvements or replacement of components with new improved components.

5. Replacement of components found defective during scheduled maintenance functions.

A typical functional flow diagram for unscheduled maintenance is presented in Figure 4.2-1.

<u>4.2.2 OLF Subsystem Definition</u>. - MORL subsystems, as previously defined by Douglas, were used to the maximum extent practicable with minor modifications as required to meet OLF requirements. In addition, new components or subsystems were added to support the cylindrical section separating the two MORLs.

In order to perform the maintenance and repair analysis, it was necessary to identify the OLF major subsystems and break these down to the replaceable component level. The major subsystems used for the OLF maintenance and repair analysis are listed below. The system checkout equipment is not included in

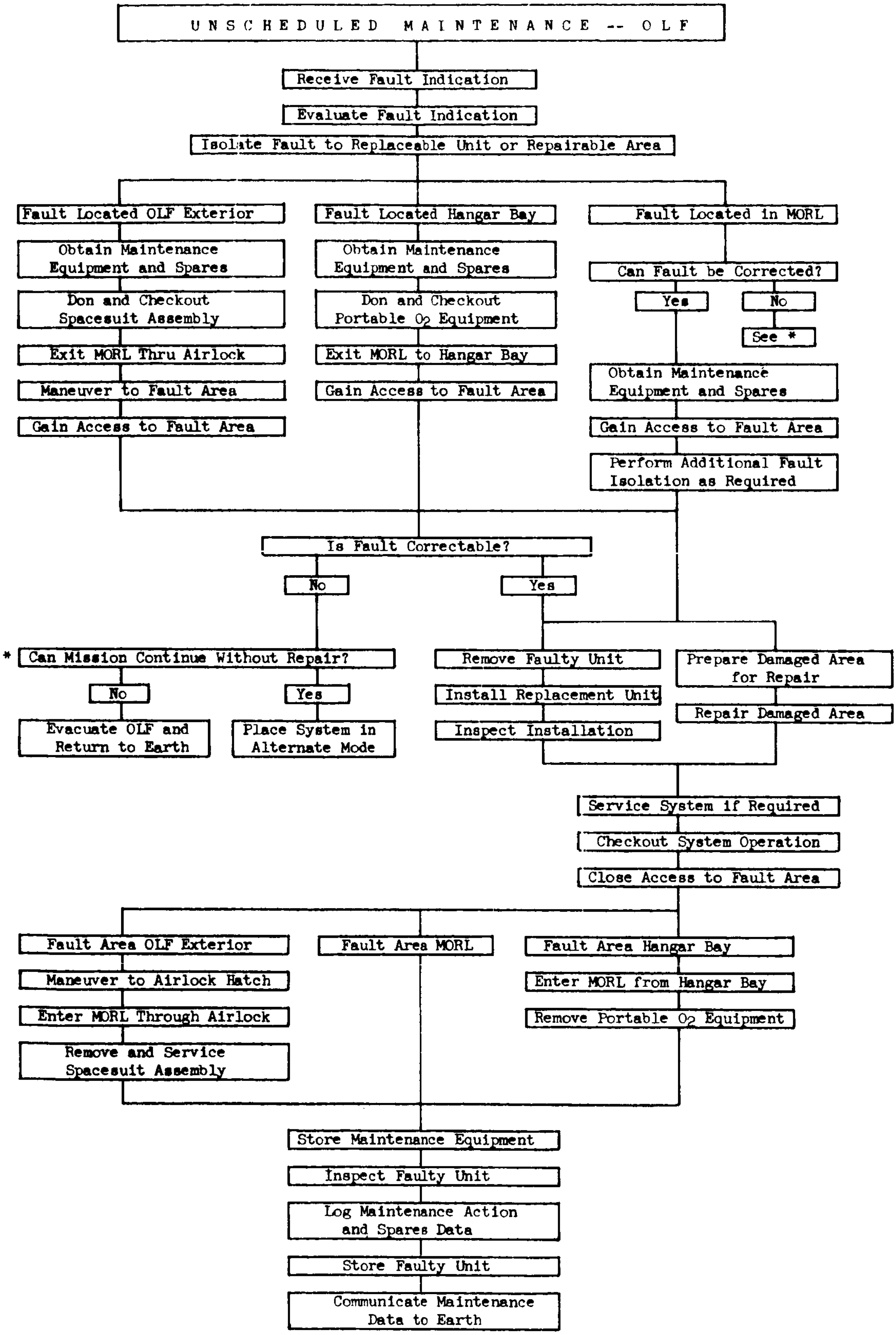


Figure 4.2-1: OLF UNSCHEDULED MAINTENANCE FUNCTIONAL FLOW

this listing because the analysis of this system was performed under a previous study.

a. Environmental Control System

b. Guidance and Navigation System

c. Attitude Control & Stabilization System

d. Communications and Telemetry

e. Electrical Power System

f. Structure and Mechanisms

g. Crew Equipment

h. Displays

No attempt to describe these systems is made here as a detailed description can be found in Paragraph 5.4.2 through 5.4.8. The system breakdown to the replaceable component level, which was used in the maintenance analysis, is shown in the maintenance and repair analysis forms, Figure 4.2-11.

4.2.3 OLF Proper Maintenance Analysis. - A maintenance analysis of the proposed OLF system was performed to define the scheduled and unscheduled maintenance that will be required to keep the OLF in an operating condition. This analysis involved the identification of the system components down to the replaceable level, quantities of each component, failure rates, spares, mass and volumes, repair time, scheduled maintenance requirements, and the maintenance resources required. The data accumulated in this analysis was recorded in the maintenance and repair analysis forms, Figure 4.2-11, which are included at the end of this paragraph.

The system breakdown into replaceable components was performed by system design personnel, using the ground rule that existing MORL systems were to be used to the maximum extent practicable. The basic OLF configuration is presented in Paragraph 5.2. Sufficient redundancy has been designed into the system so that repair time for replaceable components is not critical. Component failure rates established were based on data from General Electric Report ASD-R-05-64-1, dated May 15, 1964, which was factored down to one-tenth of values shown to reflect expected state-of-the-art growth of 20 years. In a preliminary analysis such as this where design details are not yet defined, it is not possible to account for redundant systems, cycle sensitive equipment, or other deviations from the normal; any factors that may affect reliability are noted in the "Remarks" column, so that proper consideration may be made in determining maintenance and spares requirements.

Each component was individually analyzed to determine the time, personnel, and resources required to accomplish scheduled and unscheduled maintenance. The procedure used to identify this data was to analyze each component with respect to the functions shown in the unscheduled flow diagarm, Figure 4.2-1. A summary of the maintenance required on each OLF system is presented in Paragraph 4.2.3.1.

Basic functions required to accomplish unscheduled maintenance tasks are presented in the functional flow diagram shown in Figure 4.2-1. The initial requirement for unscheduled maintenance will normally develop from display indications or scheduled maintenance inspections. Basic operational data for each system, such as measurement of pressures, temperatures, quantities, guidance and navigation data, position information, and power levels, is presented on display panels for monitoring and control of system operations. Caution and warning lights are used to signal the degradation of critical system functions which will necessitate more immediate attention and corrective action.

After a fault indication has been received, the indication will be evaluated and cross-checked with other system instrumentation to verify that the fault indication is valid. The available displays will be examined, additional tests will be made, using built-in capabilities of display console or checkout equipment; and, if required, other maintenance test equipment will be used to isolate the malfunction to a replaceable component or specific part of the system. OLF checkout and monitor requirements are adequately handled by the space checkout and launch equipment without imposing any design changes; therefore, a separate OLF checkout system is not required.

From the fault indication, it will be known whether the maintenance is to be performed in a shirtsleeve environment, in a reduced pressure area requiring supplemental O_2 support (3.5 psi), or in an unpressurized or exterior area requiring a pressurized spacesuit and backpack operation. A determination will be made of the maintenance equipment required to correct the malfunction and the spares required; the maintenance equipment, including personnel and tool tethering devices, and the spares will be obtained from storage. Some provision must be made for carrying equipment and spares while moving in zero-g environment.

If the malfunction is within the normally pressurized area, the maintenance personnel can proceed directly to fault area. If the malfunction is in a reduced pressure area, egress through an airlock with portable O_2 equipment will be required; if it is in an unpressurized area or external to the OLF, egress through an airlock in a pressurized spacesuit with a backpack will be required. Crewmen required to work in a 3.5 psia oxygen mask environment or in a pressurized spacesuit, must prebreathe pure O_2 for about 30 minutes to avoid bends before transfer to pure oxygen at 3.5 psia. For external maintenance a means of maneuvering will be necessary, either through a maneuvering unit which could be incorporated in the backpack or through the use of tethering devices and handholds. Tethering devices will be required for the maintenance equipment and spares for both exterior and interior maintenance.

A space environment factor which may affect the performance and scheduling of extravehicular maintenance is radiation hazard. This is greater at some areas in space than others. Therefore, it may be necessary to schedule extravehicular activity (EVA) to avoid high radiation parts of the orbit, if the malfunction is such that a delay can be tolerated. Additional space environment factors which must be considered during the development of EVA maintenance techniques are temperature extremes, micrometeoroids, electrostatic charges, light intensities, etc. Future space research activities and experiments should be directed toward the evaluation of these effects and the best methods to cope with them.

After access has been gained to the area of the malfunction, verification of the faulty unit will be made; additional fault isolation may be required to identify items to be replaced.

If at any time it is apparent that a malfunction cannot be corrected, the problem will be coordinated with Earth. If the problem is serious enough, it may require evacuation of the OLF and return of personnel to Earth. In most cases, an alternate mode of operation can be used until the next resupply mission, at which time the necessary maintenance equipment or spares can be brought to the OLF. Some system components were not spared initially because of their low failure rates and high mass, volumes, or costs. These items and their predicted rate of failure are shown in Para. 4.4. In all cases, the existing system is sufficiently redundant that a failure of one of these items can be tolerated until the next resupply period, which is a maximum of 90 days. At the next resupply, the required spare will be brought up to the OLF so that the failed item can be replaced.

Corrective action will generally consist of replacement of the faulty item, although in some cases, such as damage to structure, the maintenance will involve repair. During maintenance operations, provisions must be made for containing debris and fluids to prevent contamination of the area. After the necessary corrective action has been taken, the installation will be inspected, serviced as required, and checked out. Any removed access panels or equipment will be replaced. Personnel, equipment, and the removed item will return to the MORL; the maintenance equipment will be returned to storage; and the O_2 equipment, spacesuit, or backpacks serviced as required. The removed faulty unit will be inspected for any visual evidence of failure; minor tests with available maintenance equipment may also be conducted. A small repair shop will be available for minor repairs such as cleaning of parts, adjustment, or calibration of instruments, etc. The maintenance action taken, including pertinent data and observations, will be logged and the faulty item will be placed in storage for disposal. The maintenance data will also be transmitted to Earth at the next communication period.

4.2.3.1 OLF Systems Maintenance Requirements. -

A. Environmental Control System (ECS). - The OLF ECS is basically the same system as presently proposed for the MORL and includes an oxygen regeneration system. The ECS as used in this analysis also includes the life support system elements. The environment of the hangar and experiment bays, the two hub compartments, and the elevator tubes will also be maintained by the two MORL systems with minor modifications.

The major function subsystem areas of the environmental control system are: (1) atmosphere supply, (2) atmosphere purification, (3) water management, (4) waste management, (5) conditioning, (6) cooling, (7) heating, (8) heat transport, (9) pump down, (10) experiment lab, (11) repressurization, and (12) oxygen regeneration. Instrumentation is provided for measurement of pressures, temperatures, quantities, flow rates, and gas analysis. Display of this information will be used for monitoring and control of ECS operation, and for malfunction detection.

Unscheduled Maintenance. - The majority of the ECS components are located in normally pressurized areas so that maintenance can be accomplished in a shirt-sleeve environment. Some of the cooling,heating, heat transport, repressurization, and oxygen regeneration system components are located in areas which are normally pressurized to only 3.5 psia. Maintenance in these areas will involve working while wearing an O_2 mask, which is supplied from portable O_2 tanks by connection into an O_2 system outlet. Extravehicular activity is expected to be required only for repairs involving punctured tubes in the radiator. Repair will involve the use of some type of fusion joining equipment to patch the punctures. Redundant radiator panels are provided in each MORL and in the hub.

The ECS is designed so that all system malfunctions are normally repairable. In addition, there are many alternate or emergency modes of operations which give the crew additional time and flexibility so that possibility of crew abort due to failure of the ECS is very remote.

The gaseous and liquid O_2 and N_2 tanks are relatively large and heavy and the failure rate is low so spares are not initially provided in the OLF for these tanks. Spare tanks will be provided as a resupply item, as required. If a failure requiring tank replacement does occur, there is enough remaining system capability to permit normal operation until the next resupply. All other components in the system were considered for the initial spares loading.

The predicted mean time between failures (MTBF) for this system is 40.6 days. An average of 82 man-minutes is required to complete each unscheduled maintenance task.

Scheduled Maintenance. - General scheduled maintenance will be required at daily, weekly, and monthly intervals. In addition, replenishment of expendables will be required at the 90-day resupply period. The scheduled maintenance tasks and time required at each interval are as follows:

Daily - 110 man-minutes

1. Check all alarm circuits for correct operation,

2. Check quantities remaining of expendables,

3. Check N_2 flow meter reading,

4. Analyze O_2 and CO_2 gases,

5. Check water tank bacteria content,

6. Check airflow through filters and filter condition,

7. Check pressures in gaseous tanks, suit loop system, pressurized compartments, accumulators, fluid pumps, etc.

8. Check temperatures of all compartments, heat sources, heat exchangers, catalytic burners, evaporators, etc.

9. Transfer waste to storage area.

Weekly - 85 man-minutes

1. Perform detailed operational check and visual inspection of each ECS subsystem,

2. Calibrate spectrometers,

3. Check auto-initiation sequence of backup fans, motors, and pumps.

Monthly - 550 man-minutes

1. Check accuracy of system instrumentation,

2. Operate all manual valves,

3. Replace debris trap filters,

4. Replace charcoal canister cartridges,

5. Service complexing agent,

6. Service CO_2 reduction reactor with catalyst,

7. Replace O_2 regeneration carbon filters.

Resupply (90 days) - 670 man-minutes

1. Service cryogenic O_2 and N_2 tanks,

2. Service gaseous O_2 and N_2 tanks.

The average time per day required to accomplish the daily, weekly, and monthly scheduled maintenance tasks is about 138 man-minutes.

B. Guidance & Navigation System. - The basic MORL guidance configuration was used wherever possible. It provides automatic and/or manual orbit determination, attitude stabilizing rate signals, and gyro drift correction data. A backup capability for rendezvous with other spacecraft will be provided on the OLF; however, primary capability will be the responsibility of the arriving spacecraft. An autonomous navigation backup system is provided by an Apollo IMU, an Apollo sextant and telescope, and a horizon scanner providing inputs to the digital computer.

Instrumentation provided includes pitch, yaw, and roll indicator lights, integrating gyro calibration meters, computer displays, orbital track display, and flight director display. Display information available provides effective malfunction analysis to be made to a replaceable item.

Unscheduled Maintenance. - The horizon scanner installation permits replacement from inside the OLF in a shirtsleeve environment. All other components are also located inside the OLF and replacement should present no problems.

The digital computer, IMU, and sextant and scanning telescope will not be spared initially. If failure occurs, a replacement will be brought at the next resupply. Each of the two computers is triply redundant, therefore, sufficient redundancy is available to permit operation after an initial failure until a replacement unit can be provided by the next resupply vehicle. The IMU and sextant and scanning telescope are used for a second backup navigation system in case all ground links fail; therefore, because of their high mass and cost, they will not be spared initially, but will be brought during resupply missions as required.

The predicted MTBF for this system is 486.5 days. Each unscheduled maintenance task will require an average of about 118 man-minutes to complete.

Scheduled Maintenance. - General scheduled maintenance will be required only on a weekly and monthly basis. The scheduled maintenance tasks and times required at each interval as follows:

Weekly - 20 man-minutes

1. Check operation of redundant components.

Monthly - 30 man-minutes

1. Check accuracy of instrumentation,

2. Perform detailed operational check and visual inspection of system.

The average time per day required to accomplish these weekly and monthly scheduled maintenance tasks is about 3 man-minutes.

C. Attitude Control & Stabilization System. - The MORL stabilization and control system equipment is used for the OLF to the maximum extent possible and only requires modifications to incorporate relocated reaction control and orbit keeping engines and changes in the control logic. The redundant system capability provided by two complete MORL systems achieves a high degree of system reliability and versatility.

The major function subsystem areas included in this system are: (1) pressurization system, (2) propellant feed system, (3) leak detection system, (4) engines, (5) propellant tanks, and (6) control electronics. Instrumentation provided includes propellant pressures and temperatures, propellant quantities, engine operating times, valve positions, pitch, yaw and roll indications.

Unscheduled Maintenance. - The displays and controls provided are sufficient to enable effective malfunction analysis to be made. The redundancy designed into the system is adequate to retain control of the OLF while repairs are made. All components are replaceable.

The engines are designed so that the entire engine assembly can be easily removed and replaced. However, engine removal will require extravehicular work in a pressurized spacesuit. Breaking the propellant feed lines and one electrical connection will free the engine assembly for removal. Thrust mounts are designed to hold the engine in place using bolts, clamps, or other connections. All other system components are located in shirtsleeve environment areas or reduced pressure (3.5 psia) areas which will require auxiliary O_2 support to perform maintenance tasks. All components of the system except the propellant tanks were considered in determining the initial spares loading. Whenever a replacement for one of the tanks is required, it will be brought up at the next resupply (every 90 days). The propellant tanks which have a very low failure rate and high mass and volume, were considered uneconomical to spare initially. The system has enough redundant capacity to allow the loss of one tank without degradation to the system.

The predicted MTBF for this system is 40.6 days. Each unscheduled maintenance task will require an average of about 132 man-minutes to complete.

Scheduled Maintenance. - General scheduled maintenance for this system will be required on a daily, weekly, and monthly basis. In addition, replenishment of propellant will be accomplished at each resupply (90 days). The scheduled maintenance tasks and time required at each interval are as follows:

Daily - 10 man-minutes

1. Check all alarm circuits for correct operation,
2. Check system pressures and temperatures,
3. Check propellant quantities.

Weekly - 20 man-minutes

Check operation of redundant components.

Monthly - 60 man-minutes

1. Check accuracy of system instrumentation,
2. Perform detailed operational check and visual inspection of the system.

Resupply (90 days) - 240 man-minutes

Service propellant (fuel and oxidizer) tanks.

The average time per day required to accomplish the daily, weekly, and monthly scheduled maintenance tasks is approximately 15 man-minutes.

D. Communications & Telemetry System. - The OLF communication and telemetry subsystems handle the data transfer requirements of the space checkout and launch equipment, normal everyday "housekeeping" operations and the scientific experimental programs. The checkout equipment imposed the most severe requirement and since it is not part of the MORL system, the OLF system differs somewhat from that proposed by MORL. The basic communications elements are: (1) space-to-Earth VHF and "S" band, (2) OLF-to-OLV wide band TV, (3) extravehicular astronaut link, (4) OLF intercom system.

Instrumentation provided includes voltmeters, wattmeters, modulation level meters, TV monitor, indicator lights for mode of operation, clock, etc.

Unscheduled Maintenance. - All components of this system, except for the antennas, are located inside the OLF vehicle. Access to the components and their replacement can be accomplished while in a shirtsleeve encironment. The VHF and "S" band antennas will require extravehicular activity in a pressurized spacesuit to perform repair or replacement tasks. However, the inherently low failure rate of the antennas will limit the amount of maintenance required.

The predicted MTBF for this system is 130.0 days. Each unscheduled maintenance task will require an average of about 67 man-minutes to complete.

Scheduled Maintenance. - The only scheduled maintenance required for this system is a check of instrumentation accuracy and a detailed operational check and visual inspection of the system on a monthly basis. The time required for this is about 30 man-minutes, which is an average of one man-minute per day.

E. Electrical Power System. - The OLF electrical power system is basically the same as the system proposed for the MORL which uses an isotope-fueled, Brayton-cycle power generating system. However, the Brayton-cycle power system is installed in the OLF hub area instead of the MORL vehicles. The power system uses, as an energy source, two fuel blocks containing encapsulated plutonium-238 in the form of P_uO_2. Each fuel block has a planar heat-transfer surface and each supplies power to one of two power conversion loops which operate in parallel.

The power conversion loops are mounted on the fuel block shield structure which is provided with hinged shield doors on the sides to facilitate loop replacement. Two handling booms are provided to perform the loop package replacement operations. Storage space for spare loops is also provided on either side of the operating power system configuration. Maintenance of the power conversion loop will require working in a pressurized spacesuit.

In the event a failure requires a shutdown of either loop, automatic switching controls will transfer the surviving loop onto the essential bus, thus permitting power to be maintained while repairs are being completed. After shutdown of the failed loop, the thermal dump door for that loop opens to prevent overheating of the fuel block. Maintenance personnel then enter the area and disconnect the electrical umbilical, the radiator liquid connections, and the ECS liquid connections to the loop. The loop replacement then involves the following:

1. Attachment of one handling boom to the spare loop and attachment of the other handling boom to the faulty loop.

2. Opening the shield doors and removing the faulty loop to a position in line with the access door. The shield door is then closed to minimize personnel exposure to radiation.

3. Moving the faulty loop through the access door to the exterior of the vehicle for cool-down of the loop. This loop may be temporarily stowed or moved to a resupply vehicle, if available, for return to Earth.

4. Moving the spare loop from the stowed position to the area adjacent to

the fuel block from which the faulty loop was removed, and subsequently installing the spare loop around this fuel block.

All other electrical power system components are also completely redundant. Automatic transfer capability is provided in the system so failure of a component will not affect system operation. Failures will be indicated by trouble lights and failed components may be replaced immediately. Some of the electrical system components are located in a 3.5 psia pressurized area and their maintenance will require the use of auxiliary oxygen equipment. Extravehicular activity will be required for radiator repair. Repairs are expected to involve use of some type of fusion joining equipment to patch punctures in radiator tubes. Redundant radiator loops are provided.

The fuel block life is substantially longer than the OLF operating life and no replacement of a fuel block should be required.

Unscheduled Maintenance. - The switching and control circuitry senses defective units, isolates them from the system, and activates the proper indicator lights to provide information as to what has occurred. All components except the radiator are located in areas where maintenance can be accomplished in a shirtsleeve environment or with use of portable O_2 equipment. Extravehicular activity will be required for repair of the radiator.

It is expected that battery replacement will be required about once every year. Unscheduled maintenance of batteries between scheduled replacements will consist of replacing defective battery cells. Failed cells can result in gassing, excessive pressure buildup, and possible cell rupture. Therefore, it is necessary to replace failed cells promptly. Removal of the battery from the system will involve about 24 hours of elapsed time. Initially, 10 - 15 hours are required to allow internal pressures to dissipate and then conditioning of the battery will be required to assure that the old and new cells are in a similar state of charge.

The predicted MTBF for this sytem is 631 days. Each unscheduled maintenance task will require an average of about 124 man-minutes to complete.

Scheduled Maintenance. - General scheduled maintenance is required at daily, weekly, and monthly intervals in addition to yearly battery replacement. The scheduled maintenance tasks and times required at each interval include the following:

Daily - 5 man-minutes

1. Check all alarm circuits for correct operation,
2. Check battery charge levels.

Weekly - 40 man-minutes

1. Check operation of bus switching and control circuits,
2. Check and service Brayton-cycle power package.

Monthly - 20 man-minutes

1. Check accuracy of system instrumentation,

2. Perform detailed operational check and visual inspection of system.

Yearly - 960 man-minutes (2 men = 480 man-minutes)

Replace four batteries.

The average time per day required to accomplish the daily, weekly, and monthly scheduled maintenance tasks is about 16 man-minutes.

F. Structures & Mechanisms. - The OLF is initially launched with the MORL vehicles retracted within the cylindrical center structure. After orbit achievement, the MORLs are extended and locked in place, the MORL vehicles are pressurized, systems activated, elevators are installed, and secondary equipment is installed in the experiment bay, hangar bay, and docking hub.

The major subsystem areas included here are: (1) hatch mechanisms, (2) docking mechanisms, (3) logistics vehicle stowage, (4) equipment transport, (5) antenna mechanisms, (6) hangar door mechanisms, (7) centrifuge, (8) structure, and (9) power conversion loop handling mechanism.

Unscheduled Maintenance. - Maintenance of systems 1, 2, 3 and 4 listed above will generally require working in a pressurized spacesuit. It is also expected that maintenance of the hangar door mechanisms will require pressurized spacesuit activity or auxiliary O_2 support about half of the time.

The entire structure is designed to better than 99% probability of withstanding micrometeoroid impacts during the OLF mission. Therefore, maintenance of the exterior structure will consist of repairing damage caused by inadvertent collision during extravehicular activity or docking operations. If a micrometeoroid penetration of the inner skin does occur, it will be repaired from inside the OLF, whenever possible, through the use of adhesive patches or liquid sealants for small punctures. Larger punctures would be repaired using metal plugs or patches secured through some type of fusion joining process.

Maintenance of interior structures will generally consist of repairing inadvertent damage caused during equipment handling, personnel movements, etc. Repairs will be accomplished using standard metal or fabric repair equipment.

The predicted MTBF for this system is 180.6 days. Each unscheduled maintenance task will require an average of about 173 man-minutes to complete.

Scheduled Maintenance. - Scheduled maintenance of structures and mechanisms will be on a weekly basis for interior systems and on a monthly basis for exterior systems. The scheduled maintenance tasks and time required at each interval include the following:

Weekly - 80 man-minutes

1. Conduct thorough inspection of all interior structures and mechanisms that do not require pressurized spacesuit activity,

2. Lubricate mechanisms accessible from inside the OLF.

Monthly - 165 man-minutes

1. Conduct thorough inspection of all exterior structures and mechanisms (Requires pressurized spacesuit & EVA),

2. Lubricate mechanisms accessible only by pressurized spacesuit activity.

The average time per day required to accomplish these weekly and monthly tasks is about 16 man-minutes.

G. Crew Equipment. - The crew subsystem equipment includes those miscellaneous items which do not fit one of the major subsystem categories. The only items considered in the analysis were those which could be expected to require some maintenance.

Unscheduled Maintenance. - All of the equipment considered as part of the crew subsystem is located in normally pressurized areas, so that maintenance can be accomplished in a shirtsleeve environment. Malfunctions will generally be detected during normal operation of the equipment and will be readily identified. Equipment is accessible for easy replacement or repair. Malfunctions of the washer-dryer and exercise machine can be corrected by repair. Some spacesuit repair by sewing and patching or replacement of disconnect seals may be performed.

The predicted MTBF for this crew equipment is 528.5 days. Each unscheduled maintenance task will require an average of about 45 man-minutes to complete.

Scheduled Maintenance. - The spacesuits and backpacks used for extravehicular activity are checked out before and after each use and are serviced, as required, after each use. The time required to do this is included as part of the maintenance task times whenever EVA is required. The only other scheduled maintenance necessary is a monthly inspection and cleaning of the film viewing equipment, which will require about 10 minutes each or 20 minutes total, and a monthly inspection of the fire extinguishers, which will require about 25 minutes. The average time per day required to accomplish these tasks will be about two (2) man-minutes.

H. Displays. - The displays encompass the measurements and indications required to monitor the functional operations, perform fault detection, and perform fault isolation of the OLF systems. These displays are presented on the main operations console, which is closely integrated with the checkout and monitor console provided in the checkout and launch equipment. These primary consoles are located in one MORL, with secondary consoles located in the other MORL, to provide the basic display data required for its systems. A detailed identification of the necessary displays is not possible at this time because the system design is not sufficiently detailed. However, as the displays listed in the maintenance analysis forms in the appendix are believed to fairly represent the complexity of the system, as such, it is expected that the maintenance requirements presented will be represenative of the actual configuration.

Unscheduled Maintenance. - The displays will be mounted on various consoles and the installations will be designed for easy replacement of the individual lights, indicators, and instruments. The easy accessibility of the display components will facilitate rapid fault isolation and fault correction. Consequently, the display system will require a minimum of maintenance.

The predicted MTBF for this system is 93.8 days. Each unscheduled maintenance task will require an average of about 42 man-minutes to complete.

Scheduled Maintenance. - Scheduled maintenance of the displays consist of daily checks of the alarm circuits and periodic accuracy checks of the instruments. These scheduled maintenance requirements and the times required to accomplish them are included under the particular system.

Maintenance Requirements Summary. - A summary of the scheduled and unscheduled maintenance identified in the preceding paragraphs is presented in Figure 4.2-2. A further breakdown of the maintenance by skill level requirements is included in Paragraph 4.2.3.2.

A simple computer simulation program based on the data contained in maintenance and repair analysis forms was written in GPSS II language to obtain data on the failures which could be expected to occur while in orbit. The computer program was setup so that systems failures were created randomly within an assumed exponential distribution about the system mean-time-between-failure rate. A sample of 25 years of operation was taken to assure that a realistic distribution of data was accumulated. This computer program provided data for the repair (unscheduled maintenance) task time distribution shown in Figure 4.2.3, the repair time per day distribution shown in Figure 4.2-4, and the spares usage data presented in Para. 4.4.2.

SYSTEM	Man-Minutes				
	Daily	Weekly	Monthly	Resupply	Yearly
SCHEDULED MAINTENANCE					
Environmental Control	110	85	550	670	--
Guidance & Navigation	--	20	--	--	--
Attitude Control & Stabil.	10	20	60	240	--
Communications & Telemetry	--	--	30	--	--
Electrical Power	5	40	20	--	960
Structures & Mechanisms	--	80	165	--	--
Crew Equipment	--	--	45	--	--
Displays	--	--	--	--	--
TOTAL	125	245	870	910	960

UNSCHEDULED MAINTENANCE	MTBF (Days)	Ave. Man-Minutes/Task	Ave. Man-Minutes/Day
Environmental Control	40.6	82.4	2.03
Guidance & Navigation	486.5	118.1	0.23
Attitude Control & Stabil.	40.6	131.8	3.24
Communications & Telemetry	130.9	67.4	0.51
Electrical Power	631.0	124.2	0.17
Structures & Mechanisms	180.6	172.8	0.96
Crew Equipment	528.5	45.3	0.10
Displays	93.8	41.5	0.44
TOTAL (Ave.)	308.1	87.1	7.68

Figure 4.2-2: OLF MAINTENANCE WORKLOAD SUMMARY

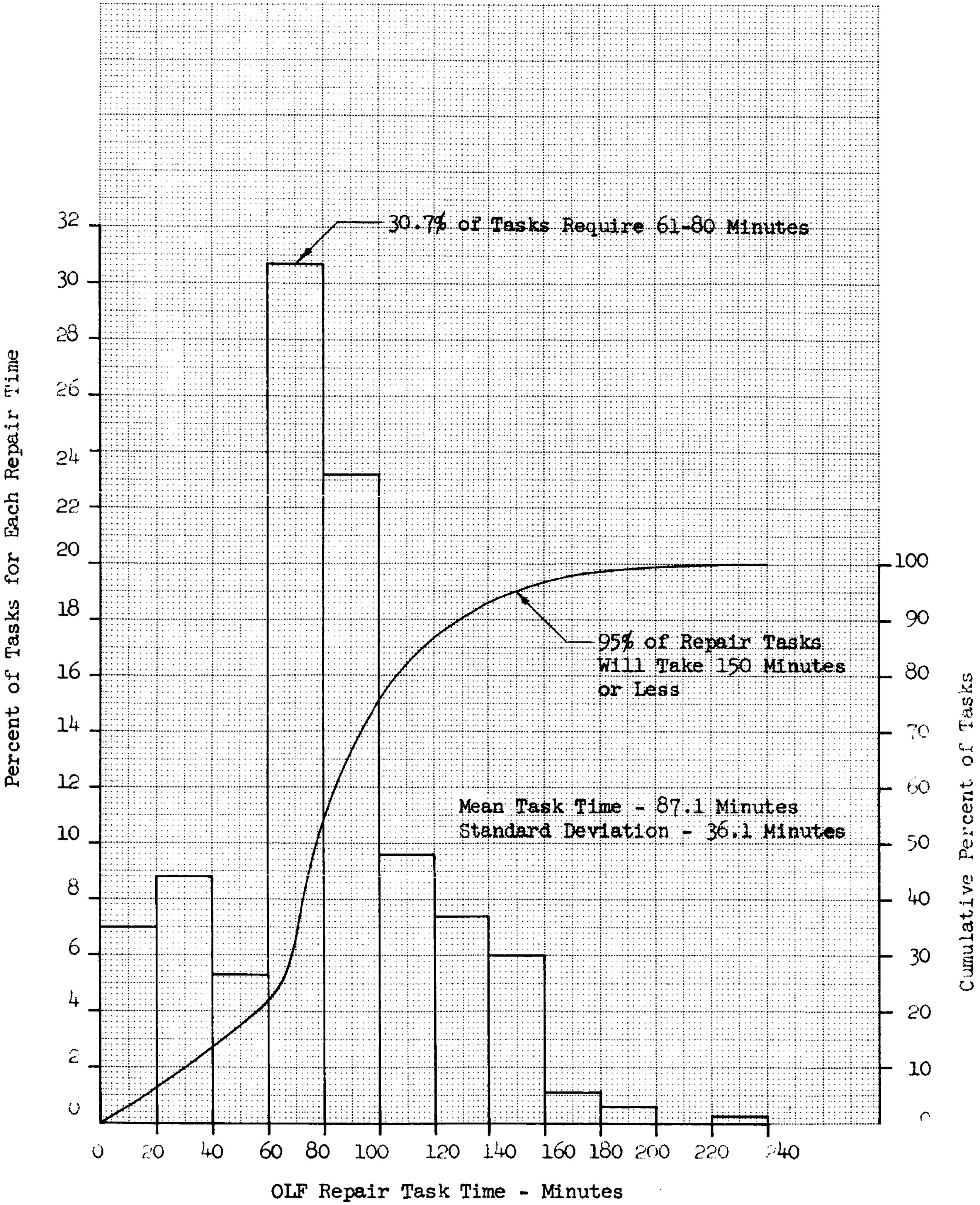


Figure 4.2-3: OLF REPAIR TASK TIME DISTRIBUTION

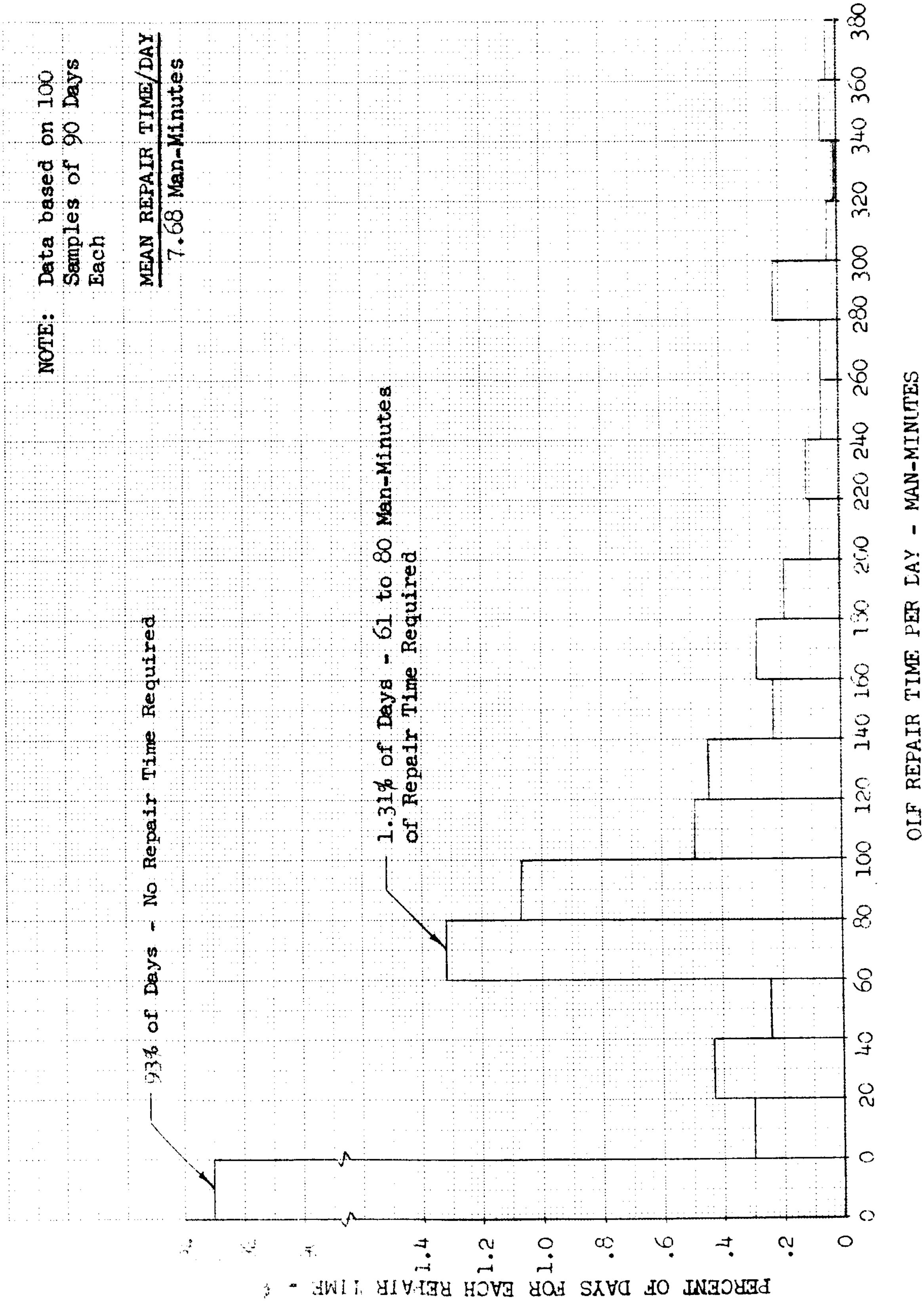


Figure 4.2-4: OLF DAILY REPAIR TIME DISTRIBUTION

Some information of general interest which is shown by these figures includes:

1. Mean repair task time = 87.1 man-minutes,

2. About 54% of the repair tasks require between 60 and 100 man-minutes,

3. 95% of repair tasks take 150 man-minutes or less,

4. Mean repair time per day = 7.64 man-minutes,

5. On 93% of days no unscheduled maintenance (repair) is required,

6. On about 2.4% of days from 60 - 100 man-minutes of maintenance is required.

A. Crew Skill Requirements. - The crew required to man the OLF system is a function of the total man-hours required to perform the operational and maintenance tasks. A detail summary of the total OLF crew requirements is presented in Para. 4.3.

The maintenance analysis identified three basic types or combinations of skills which were required to perform maintenance on the OLF. These are electrical/electronic (E/E), life support/environmental control (L/E), and structural/mechanical (S/M). The analysis indicated that most of the maintenance workload requirements were for a life support/environmental control system (L/E) skill. This is because the majority of the scheduled maintenance is generated by the environmental control system. The maintenance workloads for the electrical/electronic (E/E) and the structures/mechanical (S/M) skills are each about one-third of the L/E skill. Since some of the maintenance tasks require two men and because the man primarily trained in one of the skills may not always be available, it will be necessary that each man be cross-trained in a secondary skill. Each man will then have primary capability at one skill and a secondary capability at another skill. The workload does not justify having two men of each skill on board the OLF at all times.

B. Crew Maintenance Workload Requirements. - A summary of the maintenance time required of each type of skill as determined by the maintenance analysis is presented in Figures 4.2-5 through 4.2.-8.

Figure 4.2-5 shows the man-minutes of scheduled maintenance required for each skill level at each maintenance interval for each OLF system.

Figure 4.2-6 shows the predicted man-minutes per day of unschduled maintenance required for each skill for each OLF system.

Figure 4.2-7 shows the average man-minutes per day of scheduled maintenance for each skill level on each OLF system for the daily, weekly, and monthly tasks.

SYSTEM	DAILY			WEEKLY (7D)			MONTHLY (30D)			RESUPPLY (90D)			YEARLY (365D)		
	L/E	E/E	S/M	L/E	E/E	S/M	L/E	E/E	S/M	L/E	E/E	S/M	L/E	E/E	S/M
Environmental Control	110			70	15		470	80		670					
Guidance & Navigation					20										
Attitude Control & Stabilization			10		20			30	30			240			
Communications & Telemetry								30							
Electrical Power		5			40			20						480*	480*
Structures Mechanisms						80			165						
Crew Subsystems								20	25						
TOTAL MAN-MINUTES	110	5	10	70	95	80	470	180	220	670	0	240		480	480
MAN-MINUTES/DAY	110	5	10	10	14	11	16	6	7						

* These tasks require 2 men, one of each type.

Figure 4.2-5: SCHEDULED MAINTENANCE - MAN MINUTES/SKILL

FIGURE 4.2-6 OLF UNSCHEDULED MAINTENANCE SKILLS REQUIREMENTS

SYSTEM	AVERAGE MAN-MINUTES PER DAY			
	L/E	E/E	S/M	Total
Environmental Control	.87	1.14	.02	2.03
Guidance & Navigation	--	.17	.06	.23
Attitude Control & Stabilization	--	1.02	2.22	3.24
Communications & Telemetry	--	.51	--	.51
Electrical Power	--	.17	--	.17
Structures & Mechanisms	.20	.14	.61	.95
Crew Equipment	.02	.07	.02	.11
Displays	--	.44	--	.44
TOTAL	1.08	3.65	2.91	7.68

FIGURE 4.2-7 OLF SCHEDULED MAINTENANCE - MAN-MINUTES/DAY/SKILL

SYSTEM	Average Man-Minutes/Day for Daily, Weekly and Monthly Tasks			
	L/E	E/E	S/M	Total
Environmental Control	144	5	--	149
Guidance & Navigation	--	3	--	3
Attitude Control & Stabilization	--	4	13	17
Communications & T/M	--	1	--	1
Electrical Power	--	12	--	12
Structures & Mechanisms	--	--	18	18
Crew Subsystem	--	1	1	2
TOTAL	144	26	32	202

Additional scheduled maintenance which cannot be scheduled on a daily basis includes the servicing requirements at the 90-day resupply period and the yearly schedule replacements listed below:

	MAN-MINUTES/SKILL				
	L/E	E/E	S/M	Total Man-Minutes	Average Man-Hours Day
Resupply (90 days)	670	- -	240	910/90 days	0.17
Yearly (Battery replacements)		480	480	960/year	0.05

It is assumed that the weekly and monthly tasks would be divided so a few tasks could be accomplished each day and, thereby, distribute the workload over all of the days included in each interval. However, the servicing tasks required at each resupply period can only be accomplished at that time. The yearly scheduled replacements must also occur whenever a year's operating time on the item has accumulated. Assuming relatively few failures during the year, most of the replacement will come due at the end of each year in orbit and this scheduled maintenance would be concentrated over a number of days during this time period.

Figure 4.2-8 provides a summary of the scheduled and unscheduled maintenance workload for each skill type.

TABLE 4.2-8 OLF MAINTENANCE REQUIREMENTS SUMMARY MAN MINUTES/DAY/SKILL

	Average Man-Minutes per Day			
	L/E	E/E	S/M	Total
Scheduled Maintenance (Daily, Weekly, and Monthly Tasks)	144	26	32	202
Unscheduled Maintenance	1.08	3.65	2.91	7.68
TOTAL MAN-MINUTES/DAY	145.08	29.65	34.91	209.68
TOTAL MAN-HOURS/DAY	2.41	0.49	0.58	3.52

4.2.3.3 Maintenance Resources Requirements. - Support of the maintenance activities will require certain resources, including maintenance tools, equipment, technical data, work areas, and storage areas. Paragraph 7.1.7 discusses these resources in general terms. A small shop area is provided in each MORL, which will be used for minor repairs as required. Although the basic maintenance concept is that of component replacement, it is expected there will be a necessity for minor repairs such as cleaning of parts, adjustments and calibration of instruments, minor modifications, etc. The work shop areas will also be used for inspection and minor testing of removed faulty components prior to logging of maintenance data.

Storage for spares and maintenance equipment will be provided in each MORL and in the hub. The zero-gravity environment will present some unique storage requirements in that all equipment must be secured to prevent movement in any direction. Yet, it must be possible to gain ready access to these items whenever the need arises.

The Maintenance & Repair Analysis forms contained at the end of this section identify the basic types of equipment required to perform maintenance. One of the three basic tool boxes would be stored in each MORL and one in a hangar bay area. One set each of the remaining equipment would be located in each MORL.

This preliminary equipment is listed in Figure 4.2-9. The equipment list numbers refer to the numbers listed in the "Tools" column of the Maintenance & Repair Analysis forms.

4.2.4 <u>Integrated OLF Maintenance Requirements</u>. - This paragraph summarizes the total crew workload required to maintain the OLF and its associated systems or equipment. These systems include the OLF proper, which was summarized in Paragraph 4.2.3, the checkout and launch equipment, the orbital support equipment, and the Apollo logistics spacecraft. As the OLF crew has the responsibility for support of all this equipment, it is included as part of their workload. Any additional equipment which may be provided for a specific mission has not been considered. The checkout equipment which is provided for checkout of the orbital launch vehicle is an integral part of the OLF and, as such, is also used for monitor, checkout, and fault isolation of the OLF systems. Figure 4.2-10 summarizes the total workload requirements. Resupply and yearly scheduled maintenance tasks for the OLF proper have been included in the man-hours/day figures in this table.

EQUIPMENT NOMENCLATURE	MASS		
	EACH	QUANTITY	TOTAL
1. Maintenance tool box includes: a. Basic set of wrenches (1.5#) b. Basic set of sockets and drivers (2.0) c. Pliers,mechanics and electrical connector (1.0) d. Insulated tape (0.4) e. Basic screwdriver set (0.6) f. Tool retaining provisions (0.5) g. Personnel restraint equipment (2.0) h. Flashlight (0.5) i. Gloves (0.3) j. Technical data (5.5) * k. Vacuum cleaner (3.0) l. Multimeter (3.0) m. Mirror (0.2) n. Tool box (5.0)	25	3	75
2. Wrenches -- plumbing or tubing	1.0	2	2
3. Bags, fluid container	0.1	20	2
4. Electrical wiring repair tools	2.0	2	4
5. Lubrication kit	1.0	2	2
6. Rivet or lockbolt equipment	5.0	2	10
7. Repair kit, fabric	2.0	2	4
8. Repair kit, vehicle skin	5.0	2	10
9. Leak detection equipment	4.0	2	8
10. Temperature measuring device	1.0	2	2
11. Pressure measuring device	3.0	2	6
12. Signal generator	10	2	20
13. Oscilloscope	10	2	20
14. Battery test kit	3	2	6
15. Drill set	5	2	10
16. Frequency meter	3	2	6
17. Patch cables	5	2	10

Figure 4.2-9: OLF MAINTENANCE EQUIPMENT

EQUIPMENT NOMENCLATURE	MASS		
	EACH	QUANTITY	TOTAL
18. Fire extinguisher **			
19. Gas analysis kit	8	2	16
20. Water test kit	2	2	4
21. Air flow meter	2	2	4
22. Miscellaneous roto-bin and raw stock items	10	2	20
23. Fusion joining equipment	5	2	10
24. EVA tether and restraint equipment	5	2	10
25. Spacesuit assembly including backpack **			
26. Portable O_2 equipment **			
27. Spacesuit repair kit	2	2	4
TOTAL			265

** These items have been identified in the OLF system breakdown and are listed here only so their usage can be correlated with the maintenance analysis forms.

* Technical data will be available to cover operating and maintenance procedures for all in-orbit aspects of the OLF. However, only the technical data applicable to the particular malfunction will be carried as part of the tool box for the unscheduled maintenance task.

Figure 4.2-9: OLF MAINTENANCE EQUIPMENT (CONTINUED)

FIGURE 4.2-10 INTEGRATED OLF MAINTENANCE REQUIREMENTS
MAN-HOURS/DAY/SKILL

	SCHEDULED MAINTENANCE				UNSCHEDULED MAINTENANCE			
	L/E	E/E	S/M	Total	L/E	E/E	S/M	Total
OLF PROPER	2.39	0.44	0.53	3.36	.02	.06	.05	.13
CHECKOUT EQUIPMENT	--	0.50	--	0.50	--	.05	--	.05
LOGISTIC SPACECRAFT	0.2	0.20	0.10	0.50	.03	.03	.03	.09
ORBITAL SUPPORT EQUIPMENT	0.10	0.10	0.10	0.30	.03	.03	.03	.09
TOTAL	2.69	1.24	0.73	4.66	.08	.17	.11	.36

TOTAL MAINTENANCE WORKLOAD - 5.02 MAN-HOURS/DAY

4.2.5 Advanced Technological Requirements. - The maintenance analysis of the OLF systems has indicated numerous areas where additional study or practical experience in future manned space missions will be required to determine the best methods of overcoming the problems presented by zero-gravity environment and extravehicular pressurized spacesuit operations. It is not anticipated that activities performed in a shirtsleeve environment under zero-gravity will present any particular problems as sufficient experience will have been gained in manned space flights prior to the OLF to identify and adjust to any problems encountered. Performance of tasks exterior to the OLF while wearing a pressurized spacesuit will require considerable additional study. The spacesuit and backpack assembly, as presently designed, restricts man's movements and generally increases the time required to perform functions.

Preliminary zero-gravity effects simulation studies at Boeing have indicated that man is adaptable to this environment. It is expected that with additional detailed studies, practical methods for accomplishing space tasks could be determined. The Boeing studies were accomplished in a large water tank facility where subjects were ballasted as required to achieve neutral buoyancy. Tests were accomplished with both unpressurized wet suits and pressurized spacesuits. Even though pressurized suits decreased relative movements of different parts of the body, this was partly offset by the unexpected advantage of greatly increased freedom of gross bodily movement. Future improvements in spacesuit design will eliminate many of the present deficiencies. In general, the zero-gravity simulation studies tended to indicate that the problems associated with this environment will not be as extreme as originally expected because of man's rapid adaptability to the new conditions.

The areas wherein additional study is needed to ensure that the maintenance necessary for support of the OLF can be accomplished are as follows:

a. Requirements for personnel and tool tethers or restraints for interior and extravehicular activity (EVA).

b. Servicing of fluid systems in zero-gravity environment; liquid, gas, cryogenic.

c. Handling of fluids when disconnecting fluid lines for maintenance.

d. Prevention of scattering of debris during maintenance (filter, replacement, etc.)

e. Precautionary methods required when working on hazardous materials (LOX, O_2).

f. Capability for radiator and tank repair using some type of fusion joining process.

g. Replacement of propulsion system components which are on OLF exterior.

h. Carrying maintenance equipment and spares during interior maintenance in zero-gravity conditions and during exterior maintenance while wearing a pressurized spacesuit.

i. Transferring logistics supplies from resupply vehicle to OLF and storage in OLF.

j. Handling of large items of equipment which require two men who must coordinate their actions in zero-gravity conditions, both in a shirtsleeve environment and in a pressurized spacesuit.

k. Problems associated with extravehicular activities performed under extreme variations in light contrasts, light intensities, and temperatures.

l. Methods for decreasing the time required for transition from a shirtsleeve environment to an extravehicular environment, i. e., requirements for prebreathing pure oxygen, donning and checking out spacesuit equipment, movement through air locks, etc.

m. Evaluation of radiation effects during EVA.

n. Evaluation of electrostatic charges and their possible hazards during EVA, docking, etc.

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/CLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Atmosphere supply System	O_2 Tank Package Subcritical	5/10					90D	38.6	.23	(1) Service at 90D resupply (15 min. ea.)	225	1 L/E		NOTE: 3.5 psia - refers to reduced pressure bay areas between the MORL Auxiliary O_2 is required to work in these areas. EVA-refers to extravehicular activity. Work will require use of pressurized space-suit with backpack.
	1 Tank, subcritical O_2	5/10		.035	0.35	Repl. ↓		38.6	.23	If tank fails, complete O_2 Tank Pkg. will be replaced	150	1 L/E & 1 S/M	2, 9, 18	
	2 Heater	5/10		.071	0.71			38.6	.23	If heater fails, complete O_2 tank pkg. will be replaced	150	1 L/E & 1 E/E	2, 9, 18	
	3 Switch, pressure	5/10		1.43	14.3			.32	.001		80	1 L/E	11	
	4 HX, phase control	5/10		.035	0.35			38.6	.23	If HX fails, complete O_2 Tank pkg. will be replaced	150	1 L/E & 1 E/E	2, 9, 18	
	5 Coupling, fill	5/10		.001	0.01			.05	.0003		60	1 L/E	2.9	
	6 Coupling (2)	10/20		.001	0.02			.18	.0003		70	1 L/E	2.9	
	7 Valve, shutoff, solenoid	5/10		1.43	14.3			.14	.001		100	1 L/E	18	
	8 Valve, relief	5/10		0.33	3.3			.45	.001		90	1 L/E	18	
	N_2 Tank Pkg. subcritical	1/2					90D	17.7	.12	Service at 90D resupply (15 min. ea.)	60	1 L/E	2, 9	
	9 Tank, subcritical N_2	1/2		.035	.07			17.7	.12	If tank fails, replace complete N_2 tank package.	150	1 L/E & 1 M/S	2, 9	
	10 Heater	1/2		.071	.14			17.7	.12	If heater fails, replace N_2 tank package	150	1 L/E & 1 E/E	2, 9, 18	
	11 Switch, pressure	1/2		1.43	2.86			.32	.001		80	1 L/E	11	
	12 HX, Phase Control	1/2		.035	.07			17.7	.12	If HX fails, replace N_2 tank package	150	1 L/E & 1 E/E	2, 9	
	13 Disconnect	1/2		.007	.014			.09	.0003		70	1 L/E	2, 9	
	14 Coupling, Fill	1/2		.001	.002			.05	.0003		60	1 L/E	2, 9	
	15 Coupling	2/4		.001	.004			.18	.0003		70	1 L/E	2, 9	
	16 Valve, shutoff, solenoid	3/6		1.43	8.58			.14	.0011		100	1 L/E		
	17 Valve, Relief	1/2		.33	.66			.45	.001		90	1 L/E	11	
	O_2 Pkg. Gaseous	2/4					90D			Service at 90D Resupply (15 min. ea.)	120	1 L/E		
	18 Tank, GO_2	2/4		.007	.028	↑		32.6	.11		140	1 L/E & 1 S/M	2, 9, 18	
	19 Coupling	2/4		.001	.004			.18	.0003		80	1 L/E	2, 9, 18	
	20 Valve, shutoff, solenoid	2/4		1.43	5.72	Repl.		.14	.0011		110	1 L/E	18	

REMARKS: (1) General Scheduled Maintenance - OLF
Daily - 10 min. - Check alarm circuits; LO_2 & LN_2 quantities; N_2 flowmeter; tank, suit & hangar pressures; analyse O_2
30 days - 20 min. - operate manual valves, check instrumentation

Personnel skill code
E/E - Electrical/Electronics
L/E - Life Support/Environmental Control
S/M - Structural/Mechanical

O_2 & N_2 tanks will not be spared. If spare tank is required, it will be brought at next resupply.

Numbers refer to maintenance equipment list. It is assumed that Item No. 1 on list, "Maintenance Tool Box", as well as the SCALE system is used during all unscheduled maintenance tasks.

Figure 4.2-11: OLF MAINTENANCE ANALYSIS

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Atmosphere Supply System (Continued)	<u>PLSS Supply Pkg.</u>	1/3				Repl.	90D			Service at 90D resupply (15 min. ea.)	45	1 L/E		
	21 Tank, GO_2	1/3		.035	.105	↓		7.7	.056		140	1 L/E & 1 S/M	2, 9, 18	One pkg. is in 3.5 psia bays
	22 Coupling	1/3		.001	.003			1.8	.0003		80	1 L/E	2, 9	
	23 Valve, shutoff, solenoid	1/3		1.43	4.29			.14	.0011		110	1 L/E	18	
	<u>N_2 Pkg., Gaseous</u>	2/4					90D			Service at 90D resupply (15 min. ea.)	120	1 L/E		
	24 Tank, GN_2	2/4		.035	.140			32.3	.11		120	1 L/E & 1 S/M	2, 9	
	25 Coupling	2/4		.001	.004			.18	.0003		70	1 L/E	2, 9	
	26 Valve, shutoff, solenoid	2/4		1.43	4.29			.14	.0011		100	1 L/E		
	<u>Miscellaneous</u>													
	27 Valve, Off-on, solenoid	6/12		1.43	17.16			.59	.003		110	1 L/E		
	28 Valve, check	2/4		.033	.131			.14	.0016		100	1 L/E	2, 18	
	29 HX, N_2	1/2		.035	.07			.45	.003		130	1 L/E	2, 9	
	30 HX, O_2	1/2		.035	.07			.45	.003		130	1 L/E	2, 9, 18	
	31 Reducer, pressure	4/8		1.43	11.42			.36	.006		90	1 L/E	2, 11, 18	
	32 Sensor, pressure	2/4		1.43	5.72			.27	.0003		80	1 L/E	11	
	33 Valve, dump	2/4		.14	.56			.62	.003		90	1 L/E	2, 9	
	34 Valve, shutoff, solenoid	2/5		1.43	7.15			.14	.0011		100	1 L/E	2, 9, 18	
	35 Valve, refill	2/14		.014	.20			.86	.002		100	1 L/E	2, 9, 18	
	36 Disconnect, PLSS	2/5		.007	.035			.14	.0011		60	1 L/E	2, 9	
	37 Regulator, pressure	4/12		1.43	17.16			.68	.003		90	1 E/E	2, 18	
	38 Valve, shutoff, manual	0/4		.014	.20			.45	.005		100	1 L/E	2, 9	
	39 Flowmeter	2/4		.7	.28			.23	.003		80	1 E/E	2, 21	
	40 Valve, shutoff, manual	2/16		.014	.228			.14	.0011		100	1 L/E	2, 9	
	41 Regulator, pressure	4/23		1.43	46.6			.68	.003		90	1 E/E	2	
	42 Face Mask	4/32		3.57	114.2	↑		.23	.003		20	1 L/E		
	43 Valve, airlock dump	4/8		.14	1.14			.82	.003		110	1 L/E	2, 9	
	44 Sensor, O_2 Partial pressure	2/9		1.43	12.87			.45	.0014		80	1 L/E	11, 19	
	45 Connector, suit	6/36		.007	.26	Repl.		.18	.0023		50	1 L/E		Parts not in MORLs are in 3.5 psia bays

<u>REMARKS</u>: O_2 & N_2 tanks will not be spared. If spare tank is required, it will be brought at next resupply

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED NORL/CLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Atmosphere Supply System (Continued)	46 Valve, relief, absolute	2/4		.33	1.31	Repl.		.45	.003		80	1 L/E	11	
	47 Valve, diverter manual	2/4		.14	.56			.32	.001		90	1 L/E		
	48 Valve, Temp. Control	1/2		.143	2.86			.59	.0006		80	1 L/E	10	
	49 Valve, shutoff, manual	2/19		.014	.28			.91	.0014		100	1 L/E	2, 9	
	369 Valve, damper, manual	0/2		.014	10.28			1.13	.009		100	1 L/E	2, 9	
	370 Fan, diffuser 780 cfm	0/4		3.57	14.3			3.62	.014		90	1 E/E		
	371 Fan 650 cfm	0/4		3.57	14.3			3.94	.011		90	1 E/E		
	372 Valve, check	0/4		.33	1.31			.91	.013		90	1 L/E		
Atmosphere Purification	CO_2 Removal Pkg.	2/4								1				
	50 Canister, silica gel (2)	4/8		.29	2.3			9.1	.03		140	1 L/E	2, 3, 21	
	51 Canister, zeolite (2)	4/8		.29	2.3			6.8	.14		120	1 L/E	2, 21	
	52 Valve, diverter (2)	4/8		.14	1.14			1.18	.0014		100	1 L/E	2	
	53 Sensor, relative humidity	2/4		1.43	5.72			.45	.0014		70	1 L/E		
	54 Valve, diverter (dual)	2/4		.29	1.114			.59	.0011		110	1 L/E	2, 3	
	55 Valve, diverter (dual)	2/4		.29	1.14			.91	.0014		100	1 L/E	2	
	56 Valve, diverter (dual)	2/4		.29	1.14			.91	.004		110	1 L/E	2, 3	
	57 Valve, diverter	2/4		.14	.56			.45	.002		100	1 L/E	2	
	58 Timer	2/4		7.14	28.6			1.8	.0014		70	1 E/E		
	59 Pump, vacuum	2/4		3.57	14.3			9.1	.04		90	1 E/E	2	
	60 Valve, shutoff	2/4		.014	.056			.91	.0014		80	1 L/E		
Atmosphere Purification System	Trace Contaminant - Evap. Pkg.	1												
	61 Pump, water	4/8		2.14	17.1			1.13	.006		110	1 E/E		
	62 Valve, diverter (dual)	2/4		.29	1.14			3.04	.004		90	1 L/E	2	
	63 Valve, check	6/18		.33	5.9			.23	.0014		80	1 L/E		Some of these parts are in 3.5 psia bay
	64 Fan, CO_2/suit	6/16		3.6	57.1			2.5	.011		110	1 E/E	2	
	65 Cartridge, chemisorbent	2/4		.29	1.14			3.6	.007		100	1 L/E	21	
	66 Burner, catalytic	2/4		.29	1.14	Repl.		2.9	.009		120	1 L/E	2, 3	

REMARKS: Failure rate applies only if recharge or regeneration is done according to prearranged schedule.

1 General scheduled maintenance - OLF

Daily - 10 min. - Check alarm circuits, analyze CO_2, humidity level, CO_2 cycling, burner temp., filter condition, suit loop flow, HX temp., water separator pump pressure.

7 days - 30 min. - Calibrate sepctrometer, check auto initiation of backup fans & pumps, conduct general inspection.

30 days - 20 min. - Operate manual valves, check instrumentation.

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/CLF	PERCENT OPER TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Atmosphere Purification System (Cont.)	67 Sensor, temp	3/6		1.43	8.58	Repl.		.14	.0006		80	1 L/E	10	
	68 Valve, flow control	2/4		.14	.56			.23	.0014		90	1 L/E	21	
	69 Elbow, water separator	2/4		.001	.004			.23	.006		50	1 L/E	2, 3	
	70 Flow meter	2/4		.71	2.9			.45	.003		80	1 E/E	2, 21	
	71 HX_2 Regenerative	2/4		.05	.2			.45	.006		120	1 L/E	3	
	72 Valve, check	4/8		.33	2.64			.91	.003		80	1 L/E		
	73 Debris trap & filter	2/4		.64	2.56		30D	.77	.003	30 Days - replace filter (15 min. ea.)	75 80	1 L/E 1 L/E	21	
	74 Fan, contaminant loop	4/8		3.6	28.6			2.4	.011	Replace trap (unscheduled)	90	1 E/E		
	75 Flow meter	2/4		.71	2.9			.14	.003		80	1 E/E	21	
	76 Canister, charcoal	2/4		.29*	1.14		30D	.82	.009	30 Days - replace charcoal (15 min. ea.) Replace canister (unscheduled)	75 120	1 L/E	21	
	77 HX_1 Humidity control	2/4		.036	.14			4.8	.011		130	1 L/E	2, 3	
	78 Switch, pressure	2/4		1.43	5.71			.27	.0017		70	1 L/E	2, 11	
	79 Valve, diverter, manual	2/4		.14	.56			.32	.001		100	1 L/E	3	
	80 Valve, check	4/8		.33	2.64			.05	.0014		90	1 L/E	3	
	81 Evaporator	2/4		.036	.14			3.1	.006		120	1 L/E		
	82 Heater	1/2		.07	.14			1.05	.003		140	1 E/E	3	
	83 Lamp, ultraviolet	2/4		3.57	14.3			1.13	.009		70	1 E/E		
	84 Valve, Diverter	5/10		.14	1.43			2.9	.001		100	1 L/E		
	85 Valve, shutoff	7/14		.014	.2			.45	.0006		80	1 L/E		
	86 Valve, temp., control	3/6		1.43	8.56			.59	.0014		90	1 E/E	2, 3, 10	
	87 Sensor, temp. control	3/6		1.43	8.58			.14	.0006		70	1 E/E	10	
	88 Sensor, O_2 partial pressure	2/4		1.43	5.71			.27	.0014		70	1 L/E	9, 11, 19	
	89 Sensor, CO_2 partial pressure	2/4		1.43	5.71			.45	.0014		70	1 L/E	9, 11, 19	
	90 Valve, vent	2/4		1.43	5.71			.68	.0017		80	1 L/E	9	
	91 Valve, relief, absolute	2/4		1.43	5.71			.68	.0014		100	1 L/E	9, 11	
	92 Sensor, temp.	1/2		1.43	2.86			.14	.0006		70	1 L/E		
	93 Valve, suit bypass	2/4		.014	.057			.91	.002		80	1 L/E		
	94 Connector, suit	18/36		.001	.036	Repl.		.18	.0023		50	1 L/E		

REMARKS:

*See note on previous sheet

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED NORL OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3		REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Atmosphere Purification System (Cont.)	Miscellaneous													
	95 Gas chromatograph	1/3		2.86	6.58	Repl.		6.4	.004		70	1 E/E	one of each is 3.5 psia bays	
	96 Mass spectrometer	1/3		14.29	42.86	↓		6.4	.004		70	1 E/E		
Water Management System	Dispenser-Refrigeration Pkg.													
	97 Valve, water dispenser	5/10		.014	.14			.23	.0006		40	1 L/E	2, 3	
	98 Chiller	1/2		.036	.071			2.34	.009		120	1 L/E	2, 3	
	99 Valve, Temp. control	1/2		1.43	2.86			.59	.0011		100	1 L/E	2, 3	
	100 Sensor, temp.	1/2		1.43	2.86			.05	.0005		70	1 E/E		
	101 Refrigerator	1/2		3.57	7.14			[illegible]	.04		140	1 L/E	2, 3	
	102 Freezer	1/2		[illegible]	[illegible]			[illegible]	.04		120	1 L/E	2, 3	
	Potable Water Tank Pkg.	4/8												
	103 Valve, shutoff, manual, water	4/8		.014	.114			.14	.001		80	1 L/E	2, 3	
	104 Valve, shutoff, manual (2)	8/16		.014	.23			.5	.0011		60	1 L/E	2, 3	
	105 Valve, Temp. control	4/8		1.43	11.43			.59	.0011		80	1 E/E	2, 3, 10	
	106 Sensor, Temp.	4/8		1.43	11.43			.05	.0003		60	1 E/E	10	
	107 Heater, water tank	4/8		.07	.57			1.04	.011		150	1 E/E	2, 3, 10	
	108 Tank, potable water	4/8		.036	.28			4.6	.11		150	1 L/E	2, 3	
	109 Disconnect, quick, flex hose (2)	8/16		.007	.11			.09	.003		40	1 L/E	3	
	Pretreatment Pkg.	1/2	75% (max.)											
	110 Valve, shutoff	2/4		.014	.057			.5	.0011		80	1 L/E	2, 3	
	111 Valve, diverter	1/2		.14	.28			.18	.001		80	1 L/E	2, 3	
	112 Valve, shutoff	6/12		.014	.17			.14	.001		80	1 L/E	2, 3	
	113 Valve, check	5/10		1.43	14.3			.05	.0006		80	1 L/E	2, 3	
	114 Tank, urine processing	2/4		.14	[illegible]	↑	90D	5.4	.11	90D - service complexing agent (10 min. ea.)	50	1 L/E		
										Replace tank (unscheduled)	130	1 L/E & S/M	2, 3	
	115 Valve, shutoff	8/16		.014	.23	Repl.		.14	.001		80	1 L/E	2, 3	

REMARKS:

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/CLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Water Management System (Cont.)	116 Disconnect, urine	2/4		.007	.028	Repl.		.09	.0006		50	1 L/E	2	
	117 Pump, urinal	2/4		2.14	8.58			.91	.014		70	1 L/E	2	
	118 Tank, accumulator	2/4		.036	.14			8.7	.03		110	1 L/E	2, 3	
	119 Pump	2/4		2.14	8.58			1.13	.014		80	1 E/E	2	
	120 Sensor, conductivity	1/2		1.43	2.86			.18	.0006		100	1 L/E	2, 3	
	121 Valve, check, manual over-ride	2/4		.14	.57			.91	.006		100	1 L/E	2, 3	
	122 Valve, diverter, coolant	2/4		.14	.57			.45	.0014		90	1 L/E	2, 3	
	123 Valve, shutoff	2/4		.014	.057			.14	.0006		80	1 L/E	2, 3	
	124 Dryer, waste	2/4	50%	.11	.43		1D	3.6	.03	Daily - Transfer waste to storage area replace dryer	20 100	1 L/E 1 E/E	2, 3	
	125 Valve, relief	2/4	50%	1.43	5.7			.45	.0014		70	1 L/E	11	
Conditioning System	126 Debris Trap	1/9		.086	.78		30D	.14	.003	⚠1 30 days - replace filter (15 min. ea.)	75	1 L/E		Parts not in MORLs are in 3.5 psia bays
										Replace trap (unscheduled)	60	1 L/E	21	
	127 Fan, cabin bay, ventilation	2/12		3.57	42.86			5.9	.011		70	1 E/E	21	
	128 Valve, check	2/18		.33	5.9				.014		70	1 L/E		
	129 HX, cabin cooling	1/4		.036	.14			8.7	.021		90	1 L/E	2, 3, 10	
	130 Sensor, temp.	1/9		1.43	12.86			.14	.0006		60	1 E/E	10	
	131 Valve, temp. control	1/9		1.43	12.86			.59	.0006		90	1 E/E	2, 3, 10	
	132 Sensor, temp.	1/9		1.43	12.86			.14	.0006		60	1 E/E	10	
	133 Flow meter	1/9		.71	6.43			.23	.003		70	1 E/E	21	
	373 Fan, hub, ventilation	0/10		3.57	35.71			2.3	.009		90	1 E/E	21	
	374 HX, hub cooling	0/15		.036	.36			5.4	.017		100	1 E/E	2, 3, 10	
	375 Heater, hub heating	0/5		.07	.36			.91	.006		100	1 E/E	2, 3, 10	
	376 Heater, bay heating	0/2		.07	.14	Repl.		1.8	.009		100	1 E/E	2, 3, 10	

REMARKS: ⚠1 General scheduled maintenance - OLF
Daily - 5 min. - check alarm circuits, lab. temp. airflow through filters

7 days - 10 min. - check auto initiation of backup fan conduct general inspection.

30 days - 10 min. - check instrumentation

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED NORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Cooling System	134 Switch, pressure	1/3		1.43	4.29	Repl.		.32	.0017	1	100	1 L/E	2, 3, 11, 26	2
	135 Pump	2/6		1.43	8.58			1.5	.006		140	1 E/E	2, 3, 26	
	136 Reservoir	1/2		.035	.07			10.[illegible]	.07		120	1 L/E	2, 3, 26	
	137 Sensor, temp.	1/3		1.43	4.29			.14	.0006		100	1 E/E	2, 3, 10, 26	
	138 Valve, check	3/9		.33	2.96			.05	.0003		110	1 L/E	2, 3, 26	
	139 HX, regenerative	1/3		.05	.15			4.1	.011		140	1 L/E	2, 3, 26	
	140 Valve, diverter	2/8		.14	1.14			.41	.0003		110	1 L/E	2, 3, 26	
	141 Valve, bypass	1/3		.14	.43			.41	.0014		110	1 L/E	2, 3, 26	
	142 Accumulator	2/6		.035	.21			1.4	.04		100	1 L/E	2, 3, 26	
	143 Valve, shutoff	1/3		.014	.043			.14	.001		110	1 L/E	2, 3, 26	
	144 HX, water to coolant	1/2		.035	.07			5.9	.07		150	1 L/E	2, 3, 26	
	145 Disconnect, quick	2/6		.007	.04	Repl.		.27	.0011		90	1 L/E	2, 9, 26	
	146 Radiator (integral with OLF structure)	2/6		.007	.04	Repair		.91	.006	Maintenance consists of repairing punctured radiator tubes	180	1 S/M & 1 L/E	8, 23, 24, 25	Extravehicular activity (EVA) required
	377 Reservoir	0/1		.036	.07	Repl.		6.8	.025		120	1 L/E & 1 S/M	2, 3	
	378 HX	0/1		.036	.07			4.5	.011		150	1 L/E	2, 3, 10	
Heating System	Heating Circuit	1/2								*1				
	147 HX - Radio isotope	1/2		.043	.086			30.8	.07		150	1 L/E & 1 E/E	2, 3, 10, 26	Same as 2 for cooling circuit.
	148 Pump	1/2		1.43	2.86			1.6	.006		130	1 E/E	2, 3, 26	
	149 HX	1/2		.036	.07			5.0	.07		150	1 L/E	2, 3, 10, 26	
	150 Valve, temp. control	1/2		1.43	2.86			1.13	.006		110	1 E/E	2, 3, 10, 26	
	151 Sensor, temp.	1/2		1.43	2.86			.14	.006		90	1 E/E	10	
	152 Reservoir	1/2		.036	.07			6.0	.03		120	1 L/E & 1 S/M	2, 3, 26	
	153 Valve, Shutoff	1/2		.014	.029			.14	.003		100	1 L/E	2, 3, 26	
	154 Accumulator	1/2		.036	.07	Repl.		2.4	.04		120	1 L/E	2, 23, 26	

REMARKS: 1 General scheduled maintenance - OLF
Daily - 10 min. - check alarm circuits, backup radiator panel accumulator pressure, HX inlet temp., filter, pressure drop.
7 days - 5 min. - check auto initiation of backup pump & backup radiator panel.
30 days - 30 min. - operate manual valves, check instrumentation conduct general inspection.

*1 General scheduled maintenance - OLF
Daily - 5 min. - Check alarm circuits, heat source temp. Filter pressure drop, accumulator low level Signal & pump shutdown.
30 days - 20 min. - Check instrumentation Conduct general inspection

2 All cooling & heating system components are located in 3.5 psia bays, except the radiators. Auxiliary O_2 supply is required to work in these areas.

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL./REPR.	MAINTENANCE FUNCTION SERVICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Heat Transport System	155 Switch, pressure	1/3		1.43	4.29	Repl.		.27	.0014	1	100	1 L/E	2, 3, 11, 26	2
	156 Valve, check	1/4		.33	1.31			.45	.0014		110	1 L/E	2, 3, 26	2
	157 Accumulator	1/3		.035	.11			1.4	.04		80	1 L/E	2, 3	
	158 Pump, water	2/6		1.43	8.58			1.6	.014		130	1 E/E	2, 3, 26	2
	159 HX, Regenerative	1/2		.05	.1			5.9	.006		100	1 L/E	2, 3, 10	
	160 Heater	1/3		.07	.21			5.0	.06		100	1 E/E	2, 3, 10	
Pump Down System	161 Pump, vacuum	1/3		3.57	10.7			17.2	.03		120	1 E/E		
	162 HX, Intercooler	2/7		.035	.25			4.8	.07		110	1 L/E	2, 3	
	163 Valve, shutoff, solenoid	3/12		1.43	17.15			.54	.003		90	1 L/E		
	164 Valve, check	1/5		.33	.165	Repl.		.68	.006		90	1 L/E		
	165 Tank, storage	1/3		.035	.11	Repair		.9	.006		140	1 S/M	2, 23, 24	
	379 Valve, diverter, dual	0/1		.28	.28	Repl.		1.36	.006		100	1 L/E		
	380 Pump, vacuum	0/1		3.57	3.57			11.3	.03		140	1 E/E		
Experiment Lab.	166 Burner, catalytic	1/2		.28	.57			2.9	.011	3	90	1 L/E	10	
	167 HX, Regenerative	1/2		.05	.1			6.3	.006		100	1 L/E	10	
	168 Canister, Charcoal	1/2		.28	.57		30D	.82	.014	30 Days - replace charcoal (15 min. ea)	30	1 L/E		
										Replace canister (unscheduled)	120	1 L/E	21	
	169 Valve, shutoff manual	2/4		.014	.057			.45	.014		80	1 L/E		
	170 Valve, diverter, temp. control	1/2		1.43	2.86			2.0	.001		100	1 L/E	10	
	171 Fan, contaminant control	2/4		3.57	14.3			2.4	.011		90	1 E/E	21	
	172 Debris trap & filter	1/2		.64	1.29		30D	.77	.003	30 Days - replace filter (15 min. ea)	30			
										Replace trap (unscheduled)	70	1 L/E	21	
	173 Lamp, ultraviolet	1/2		3.57	7.14			1.13	.009		70	1 E/E		
	381 Filter, chemisorbent	1/2		.28	.57	Repl.		3.6	.02		100	1 L/E	21	

REMARKS:

1 General scheduled maintenance - OLF
Daily - 1 min. - check alarm circuits, HX outlet Temp., accumulator level, electronics outlet temp.

2 These components are located 3.5 psia bays.
See comments in 2 for cooling system.
For remaining components, those not located in the MORLs are in the 3.5 psia bays

3 General scheduled maintenance - OLF
Daily - 10 min - check alarm circuits, burner temp., filter condition, HX temp
7 Days - 5 min - check auto initiation of back-up fan
30 Days - 10 min - operate manual valve, check instrumentation

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Guidance and Navigation System	175 Two-axis horizon scanner	2/4	5	5.7	11.43	Repl		5.9	.005	[3] Replace horizon scanner (see [2] below)	120	1 E/E		
	176 Inertial rate integrating gyro	6/12	50	5.71	34.2			.45	.0002	Replace gyro easy access	80			
	177 Inertial rate integrating Gyro control electronics	6/12	50	.39	2.36			.23	.001	Replace module. Easy access	80		13	
	178 Rate gyro	3/6	50	4.29	12.86			.23	.0001	Replace gyro. Easy access	80	1 E/E		
Additional equipment to existing MORL. All other equipment on this list is contained in each MORL vehicle	179 Inertial measuring unit (IMU-Apollo)	1/1	1	20	20			2.6	.003	See [1] below	90	1 E/E & 1 S/M	13	
	180 Apollo sextant and scanning telescope	1/1	1	.29	.29			16	.03	Replace sextant and/or scanning telescope	90	1 E/E		
	181 Digital computer*	1/2	10	3.57	3.57			31	.06	Module replacement	240	1 E/E & 1 S/M	13	
	182 Single axis horizon detector head	2/4	5	.71	1.43			.45	.0001	Replace horizon detector See [2] below	120	1 E/E		
	183 Single axis horizon detector electronics	1/2	5	.29	.29	Repl.		.45	.0011	Replace package	80	1 E/E	13	

REMARKS:

- * This is the main MORL Saturn V computer used for all subsystem data processing and computer requirements. Computer has sufficient redundancy built in that airborne spare is not required. Spare will be furnished at a regular resupply if replacement is indicated.
- [1] This unit is a second backup used only when all ground links fail. Due to relatively high cost and weight, the advisability of carrying a spare is questionable. If fails, will bring spare at next resupply.
- [2] For easy replacement of these sensors, they must be mounted inside the vehicle with a window providing the field of view. In case of the horizon scanner, a germanium window would be necessary since it is an infrared device. If they must be mounted outside, redundant sensor locations would be necessary as spares.
- [3] General Scheduled Maintenance - OLF
  - 7 Days - 20 min. - Check operation of redundant components
  - 30 Days - 30 min. - Check instrumentation

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL OLF	PERCENT OPS. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Reaction Control System		1/MORL 2/OLF								1 2				
	Pressurization System													
	184 Fill Disconnect	1/2		.007	.014	Repl.		.09	.0003		100	1 S/M	2, 18	
	185 Fill Solenoid	2/4		1.43	5.71			.36	.0011		100			
	186 Vent Solenoid	8/16		1.43	22.6			.36	.0011		100			
	187 Burst Disc	5/10		.14	1.43			.09	.0003		80			
	188 Valve, Relief	5/10		.33	3.26			.36	.0011		110			
	189 Filter	2/4		.64	2.57			.09	.0006		120			
	190 Valve, Solenoid Control	4/8		1.43	11.43			.55	.0011		100			
	191 Regulator	2/4		1.43	5.71			1.13	.003		120		2, 18	
	192 Switch, pressure	1/2		1.43	2.86			.09	.0006		100		2, 11, 18	
	193 Valve, check	4/8		.014	.11			.18	.0011		110		2, 18	
	194 Valve, isolation, solenoid	8/16		1.43	22.8			.36	.0011		100		2, 18	
	195 Valve, isolation, manual	16/23		.014	.46	Repl.		.23	.001		100	1 S/M	2, 18	
	196 Valve, Purge control solenoid	2/4		1.43	5.71			.36	.0011		110	1 S/M	2, 18	
	197 Valve, Relief, back pressure	2/4		.33	1.31			.56	.0011					
	198 Disconnect, vent	2/4		.007	.026			.89	.0003		90			
	Propellant Feed System													
	199 Fill disconnect	2/4		.007	.028			.09	.0003		100			
	200 Fill solenoid	2/4		1.43	5.71			.45	.0011		100			
	201 Recirculation solenoid	2/4		1.43	5.71			.45	.0011		110			
	202 Disconnect, Recirculation	2/4		.007	.028			.09	.0003		100			
	203 Disconnect, purge	2/4		.007	.028			.09	.0003		100			
	204 Valve, purge check	4/8		.014	.11			.09	.0006		100			
	205 Valve, feed line check	4/8		.014	.11			.18	.0011		120		2, 18	
	206 Filter, feed line	4/8		.64	2.57			.16	.0011		120		2, 18	
	207 Valve, Isolation, manual	12/24		.014	.34			.23	.001		100		2, 16	
	208 Valve, engine purge	16/32		1.43	45.7			.14	.0006		100		2, 18	
	209 Prevalves, engine	32/64		1.43	91.4			.36	.0011		130		2, 18	
	210 Leak detector	32/64		1.71	109.	Repl.		.13	.0003		130	1 S/M	2, 18	

REMARKS: 2 All reaction control systems components are located in area between MORL hangar & operations area, except for control engines which are located on exterior of MORL.

1 General scheduled maintenance - OLF
Daily - 10 - min - check alarm circuits, system pressures & temperatures, tank quantities
days - 2. min. - check operation of redundant components
30 days - 60 min. - check instrumentation conduct general inspection

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Reaction Control System (cont'd)	Leak Detection System													
	211 Solenoid, leak check	45/90		1.43	128.6	Repl.		.27	.001		100	1 S/M	2, 18	
	212 Transducer, pressure	45/90		1.43	128.6			.09	.0003		100	1 S/M	2, 11, 18	
	213 Disconnect	4/8		.007	.057			.09	.0003		90	1 S/M	2, 18	
	214 Engine, attitude control	12/24	25/yr	7.3	175.2			1.22	.03		150	1 S/M & 1 E/E	2, 24, 25	EVA req'd
	215 Engine, orbit keeping	4/8	12/yr	3.5	42.0			3.7	.04		150	1 S/M & 1 E/E	2, 24, 25	EVA req'd
	216 Tank assembly, propellant	4/8		.036	.29	Repl.	90D	*59	.34	Replace Tank (unscheduled)	210	1 S/M & E/E	2, 18	
										Service at 90D resupply (30 min ea)	240	1 S/M		
Control Electronics		1/MORL 2/OLF					7D			See 1			12, 13, 16 Typical all control electronics components	
	226 Actuator selection logic	3/6		7.14	21.43	Repl.		.45	.0006		80	1 E/E		
	227 Signal conditioning	6/12		8.58	51.4			.23	.0003		80			
	228 Signal processing	6/12		8.58	51.4			.68	.001		80			
	229 Pitch-yaw control logic	4/8		4.0	16			.14	.0003		80			
	231 Valve drive & hard over monitor	32/64		.07	22.8			.23	.0003		80			
	233 Compensation electronics	6/12		1.43	8.58			.32	.0003		80			
	234 Orbitkeeping & update	1/2		2.86	2.86			1.36	.003		80			
	235 Orbit maintenance controller	1/2		14.29	14.29			2.7	.006		80			
	236 Spin control & logic	1/2		10	10			1.8	.006		80			
	237 Accelerometer	1/2		.57	.57			.23	.0001		80			
	238 Regulated power supply	2/4		2.14	4.29	Repl.		3.6	.006		90	1 E/E		

REMARKS: 1 The control electronics in one MORL will be redundant, therefore, the spares & maintenance will be based on only one set of electronics operating. Every 7 days check operation of redundant components - 20 min.

* Tank will not be spared. If spare tank is req'd, it will be brought at next resupply

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Communications & Telemetry System	239 VHF/FM Transmitter	1/2	10%	42.86	42.86	Repl.		.91	.0014	*[1]	70	1 E/E	12, 13, 16	
	240 VHF/FM Receiver	1/2	10%	28.57	28.57			1.36	.0014		70		12, 13, 16	
	Unified "S" Band Transceiver		10%											
	241 Power Amplifier	1/2		5.71	5.71			13.6	.006		80		12, 13	
	242 Premodulation Processor	1/2		1.43	1.43			6.7	.006		80		12, 13	
	243 Dual Transponder	1/2		28.57	28.57			14	.03		80		12, 13, 16	
	244 VHF Antenna	2/4	10%	2.28	4.56			.23	.0006		180		24, 25	EVA Required
	245 "S" Band Antenna	2/4	10%	414	2.28			.91	.006		180		24, 25	EVA Required
	246 VHF Multicoupler	1/2	10%	1.0	1.0			1.36	.0006		90		12, 13	
	247 "S" Band multicoupler	1/2	10%	.71	.71			.23	.0006		90		12, 13	
	248 Intercom Master Station	1/2	100%	2.14	4.29			.91	.006		60			
	249 Intercom Slave Station	4/12	30%	1.43	17.1			.23	.0014		60			
	250 50 MC Eva Transceiver (incl. with backpack)	3/12	1%	7.14	42.86			.91	.0014		40		12, 13, 16	
	251 50 MC Whip Antenna (incl. with backpack)	3/12	1%	.71	4.29			.23	.0006		60		12, 13, 16	
	252 TV Cameras	3/6	30%	8.58	51.4			4.5	.006		60		12, 13	
	253 TV Monitors	3/6	30%	7.85	47.1	Repl.		11.3	.03		80	1 E/E	12, 13	
Electrical Power System	254 Brayton cycle power conversion loop	0/2		34.5	69	Repl.		183	.5		150	1 E/E 1 S/M	2,8,10,24,25	EVA Req'd to replace power pkg. & use of remote handling arms req'd
							7D			[1] Check & serve as req'd (15 min ea)	30	1 E/E	5	
	255 Reverse current relays	0/4		.001	.004			2.5	.006		80	1 E/E	4	
	256 Battery control logic modules	0/4		2.86	11.44			5.5	.009		100		4	
	257 inverters	0/4		.71	2.84			10.9	.03		80		4	
	258 Main D.C. voltage regulators	0/4		.43	1.72			10	.009		100		4	
	259 Battery Charger regulators	0/4		.57	2.28			8.6	.009		80	1 E/E	4	
	260 Batteries	0/4		2.86	11.44	Repl.	1 yr	87	.04	1 Yr. scheduled replacement (120 ea)	480	1 E/E & 1 S/M	14	2
						Repair		3.6	.0017	Repair battery by cell replacement	150	1 E/E	14	
	261 Battery voltage regulator	0/4		.43	1.72	Repl.		6.8	.009		100	1 E/E	4	

REMARKS:

*[1] General Scheduled Maintenance OLF
30 days - 30 min - check instrumentation

[2] Battery will be out of operation about 24 hours during cell replacement, although man will be involved only 2.5 hours.

[1] General Scheduled maintenance - OLF
Daily - 5 min - check alarm circuits, check battery charge level
7 - days 40 min - check bus switching & control operations
check & service brayton cycle power package
30 - days - 20 min - check instrumentation

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^-6)	TOTAL FAILURE RATES (HRS/10^-6)	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Electrical Power System (Cont'd)	393 Frequency changers	0/4		1.3	4.2			14.5	.016		120	1 E/E	4	
	394 Transformer - Rectifiers	0/4		.7	2.8			17.2	.03		90	1 E/E	4	
	395 Radiator	0/2		.007	.014	Repair		.91	.006	Maintenance consists of repairing punctured radiator tubes	180	1 E/E & 1 S/M	8,23,24,25	EVA Required
	396 Coolant Motor Pump Package	0/4		1.5	6.0	Replace		5.5	.009		150	1 E/E	2, 25, 26	
Displays - Environmental Control System		1/MORL 2/OLF								Scheduled maintenance checks of display system instrumentation are included under the individual system analysis				
	262 Warning lights	35/70		.21	15	Repl.		.05	.0001		20	1 E/E		
	263 Caution Lights	18/36		.21	7.7			.05	.0001		20			
	264 Quantity indicators	14/28		.29	8.0			.14	.0003		40			
	265 Pressure indicators	22/44		1.43	62.8			.14	.0003		40			
	266 Flowmeters	7/14		.71	10			.14	.0003		60			
	267 Temperature indicators	16/32		1.43	45.7			.14	.0003		40			
	268 Humidity indicators	4/8		1.43	11.43			.14	.0003		60			
	269 Partial Pressure indicators	10/20		1.43	28.57			.14	.0003		70			
	270 Pump pressure differential indicators	5/10		1.43	14.29			.14	.0003		70			
	271 Water conductivity meter	1/2		.71	.143			.09	.0003		70			
	272 Trace contaminants meter	1/2		.71	1.43			.14	.0003		80			
	273 Radiation Meter	1/2		2.86	5.71	Repl.		.23	.0006		60	1 E/E		
DISPLAYS Reaction Control & Stabilization System and Guidance and Navigation System	274 Lights	120/240		.21	51.4	Repl.		.05	.0001		20	1 E/E		
	275 Digital Readout indicator	20/40		.57	22.8			.18	.0001		40			
	276 Gimbal Angle indicator	3/6		.014	.086			.14	.0001		40			
	277 CMG Speed Indicator	4/8		1.71	13.7			.14	.0001		40			
	278 Pressure indicator-Propellant	1/2		1.43	2.86			.14	.0003		50			
	279 Temp. indicator-propellant	1/2		1.43	2.86			.14	.0003		50			
	280 Orbital Track Display	1/2		5.71	11.43			.45	.002		80			
	281 Flight Director Display	1/2		21.43	42.86			.45	.003		80			
	282 Range Display	1/2		1.43	2.86			.36	.003		60			
	283 Elevation Angle Indicator	1/2		.014	.029	Repl.		.14	.0001		40			

REMARKS:

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/CLF	PERCENT OPER TIME	FAILURE RATE OF EACH ITEM ($HRS/10^{-6}$)	TOTAL FAILURE RATES ($HRS/10^{-6}$)	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
DISPLAYS (Cont'd) Reaction Control & Stabilization System and Guidance and Navigation System	284 Azimuth Angle Indicator	1/2		.014	.029	Repl.		.14	.0001		40			
	285 Signal Output Meters	4/8		1.43	11.43			.14	.0001		40			
	286 Switch - Two Position	55/110		.003	.31			.05	.0001		30			
	287 Switch - Selector	18/36		.014	.51	Repl.		.05	.0001		40	1 E/E		
Displays - Communication and Telemetry	288 Lights	12/24		.21	5.14	Repl.		.05	.0001		20	1 E/E		
	289 Switch - Two position	19/38		.003	.11			.05	.0001		30			
	290 Switch - selector	16/32		.014	.46			.05	.0001		40			
	291 Digital Readout Indicator	4/8		.57	4.56			.18	.0001		40			
	292 Voltmeter	1/2		1.43	2.86			.23	.003		40			
	293 Wattmeter	1/2		1.43	2.86			.23	.003		40			
	294 TV Monitor	1/2		4.29	5.85			3.6	.0003		30			
	295 Modulation Level Meter	1/2		1.43	2.86			.14	.0002		50			
	296 Clock	1/2		2.14	4.29	Repl.		.36	.0003		40	1 E/E		
Displays - Electrical Power	297 Lights	34/68		.21	14.6	Repl.		.05	.0001		20	1 E/E		
	298 Switch - Two position	24/48		.003	.14			.05	.0001		30			
	299 Switch - Selector	12/24		.014	.034			.05	.0001		40			
	300 Voltmeter	3/6		1.43	8.58			.23	.003		40			
	301 Ammeter	3/6		1.43	8.58			.23	.003		40			
	302 Frequency meter	1/2		1.43	2.86			.23	.003		40			
	303 Digital Readout indicator	2/4		5.71	2.28	Repl.		.18	.0001		40	1 E/E		

REMARKS:

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM $(HRS/10^{-6})$	TOTAL FAILURE RATES $(HRS/10^{-6})$	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Latch Mechanisms	304 Latch, 2-way, vacuum (E)	0/5	.5	.29	.14	Repair	7D	2.3	.004	Inspect & lubricate latch mechanisms every 7 days (20 min) Replace latch	20 150	1 S/M 1 M/S & L/E	24, 25 5	Pressure suit repair req'd for one-half of the vacuum latch repair
	305 Latch, 2-way, pressure (H)	0/5	1.0	.29	.14			2.3	.004		90			
	306 Latch, 2-way, pressure quick open (G)	0/4	5.0	2.86	.57			2.3	.004		90			
	307 Latch, 2-way, vacuum (H)	0/5	.5	.29	.14			3.2	.004		150		24, 25	
	308 Latch, 2-way, vacuum (H)	0/4	.1	.29	.14	Repair	7D	1.8	.003		100	1 S/M & L/E	24, 25	
Docking Mechanisms	313 Damper, logistics dock	0/12	.05	3.57	4.29	Repl.	30D	18.1	.06	*Inspect & lubricate docking mechanisms every 30 days (30 min) replace damper	30 180	1 S/M 1 S/M 7 1 L/E	5, 24, 25	Pressure suit repair req'd for docking mechanisms
	314 Clamp, logistics dock (M)	0/12	.05	14.29	17.1			13.6	.06		180			
	315 Damper OLV/Tanker Dock	0/6	.02	3.57	.43			91	.14		240			
	316 Clamp, OLV/Tanker Dock (M)	0/6	.02	14.29	1.71			68	.14		240	1 S/M & 1 L/E		
	317 Motors, Reversing, Logistics	0/12	.05	3.57	4.29			2.3	.011		150	1 E/E		
	318 Switch, 3-position (H)	0/12	.05	.07	.14			.14	.0014		120	1 S/M		
	319 Drive, Clamp, Logistics	0/12	.05	14.29	17.1			1.8	.014		150	1 S/M		
	320 Drive, Clamp, OLV/Tanker	0/6	.02	14.29	1.71			5.5	.004		180	1 S/M & 1 L/E		
	321 Motor, reversing, OLV/Tanker	0/6	.02	3.57	.43			9.1	.02		160	1 E/E & 1 S/M		
	322 Transducer, Limit	0/12	.05	2.14	2.57	Repl.		1.4	.006		100	1 S/M	24, 25	
Logistics Vehicle Stowage	323 Clamp (M)	0/18	.02	14.29	5.14	Repl.	30D	6.8	.06	*Inspect stowage system (15 min)	15 150	1 S/M 1 S/M & 1 L/E	24, 25	Pressure suit req'd for repair of stowage equip.
	324 Lever (M)	0/18	.02	.71	.29			13.6	.06		150	1 S/M		
	325 Motor, reversing	0/12	.02	3.57	.86			3.6	.02		150	1 E/E	24, 25	
	326 Switch, 6-position (H)	0/6	.02	1.43	.14			1.4	.006		120	1 E/E	24, 25	

REMARKS: (H) Hand Operated
(M) Motor Operated

* This will be inspected at same time as OLF exterior structure. Time for egress and ingress of OLF is included under structure inspection time.

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MOBL/CLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Equipment Transport (hangar)	327 Clamp (H)	0/6	.02	14.29	1.71	Repl.	7 D	.45	.011	Inspect transport system (20 min) & lubricate as req'd.	20 100	1 S/M 1 S/M	5	
	328 Cable/Puller (M)	0/6		8.58	1.14			1.8	.03		120	1 S/M		
	329 Rollers, guide, support	0/6		2.14	.29			2.7	.03		120	1 S/M		
	330 Motor	0/2		3.57	.14			.91	.003		110	1 E/E		
	331 Drive, Axle, reduction	0/2		10.71	.43			3.6	.03		130	1 S/M		
	332 Motor, reversing	0/6		3.57	.43			.45	.003		110	1 E/E		
	333 Cable/Drum (M)	0/6		8.58	1.14			1.4	.006		120	1 S/M		
	334 Brake/Clutch (S)	0.6		2.86	.43			.91	.003		120	1 S/M		
	335 Controls, Box (H)	0/6	.02	2.86	.43	Repl.		1.4	.004		80	1 S/M		
Antenna Mechanisms	336 Motor	0/1	.5	3.57	.014	Repl.	7D	1.8	.006	Inspect & lubricate antenna mechanism every 7 days (5 min)	5 100	1 S/M 1 E/E		
	337 Drive, antenna, radar	0/1	.5	7.14	.014			1.4	.006		120	1 S/M		
Hangar Door Mechanisms	338 Motor, Reversing	0/1	.1	3.57	.014		7D	2.3	.011	Inspect & lubricate hangar door mechanisms every 7 days (10 Min)	10 100	1 S/M 1 E/E	5	About 1/2 of repair will require use of pressure unit or auxiliary O_2
	339 Assy, travel/lock	0/1	.1	7.14	.014			1.8	.014		140	1 S/M		
	340 Latches, open/closed/lock (M)	0/6	.1	2.14	.014			1.8	.011		150	1 S/M		
	341 Rollers, guide, support	0/2	.1	2.14	.014			1.8	.014		130	1 S/M		
	342 Drive, chain, sprocket	0/1	.1	28.57	.014			1.8	.03		150	1 S/M		
	343 Switch, 3-position (H)	0/1	.1	1.43	.014	Repl.		.45	.003		100	1 E/E		

REMARKS:

(H) Hand Operated

(M) Motor Operated

(S) Solenoid Operated

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED NORL/CLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Centrifuge	349 Brakes, Dynamic (M)	0/1		1.43	1.43	Repl.	7D	1.8	.003	Inspect & lubricate centrifuge every 7 days (15 min)	15	1 S/M	5	
	350 Brake, positive, lock (M)	0/2		1.43	2.86			1.8	.006		110			
	351 Clutch, drive	0/1		28.57	28.57			1.8	.006		140			
	352 Drive, V-belt	0/1		50	50			1.8	.006		110	1 S/M		
	353 Motor, variable speed	0/1		7.14	7.14			3.6	.02		120	1 E/E		
	354 Controls (E)	0/2		2.86	5.71			.9	.009		100	1 E/E		
	355 Rollers, guide, support	0/2		2.14	4.29			6.8	.03		100	1 S/M		
	356 Adjuster, cab attitude	0/2		4.29	8.58			.14	.011		120	1 S/M		
	357 Adjuster, seat attitude	[illegible]		1.43	2.86			.45	.003		100	1 E/M		
	358 Accelerometers	0/2		5.71	11.43	Repl.		[illegible]	.0014		70	1 E/E		
Structure	359 Exterior Structure	1/1		.029	.029	Repair	30D	.9	.006	Inspect exterior of OLF (120 min) structure is designed to 99% probability of withstanding micro-meteoroid impacts during OLF life. Therefore, repairs will mostly be the result of collisions with equipment during EVA or docking operations.	120 180	1 S/M 1 S/M & L/E	6,8,15,23,24, 25	EVA req'd.
	360 Interior structure	1/1		.071	.071	Repair		.9	.006	Maintenance will mostly consist of repairing inadvertent damage caused during equipment handling or maintenance.	120	1 S/M	6,7,8,15,23	
Power conversion Loop Handling Mechanism	397 Power conversion loop handling mechanism (part breakdown not available at this time)	0/2	.1	20.	.02	Repair		2.3	.014		150	1 S/M	5	Pressure suit req'd for some repairs
Crew Subsystem Equipment	361 Lights	40/100		.21	21.43	Repl		.14	.0014		20	1 E/E		
	362 Washer-Dryer	1/2	10%	71.4	28.57	Repair		2.3	.006		90	1 E/E		
	363 Vacuum Cleaner	1/2	5%	14.29	2.86	Repl.		4.5	.03		20	1 E/E		
	364 Fire Extinguisher	3/12		P_s=.9995		Repl.	30D	2.3		Check Operation & condition (2 min ea) Replace extinguisher	25 20	1 L/E 1 L/E		

REMARKS:

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED MORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Crew Subsystem Equipment (Cont.)	365 Exercise Machine	1/2	10%	10.71	4.29	Repair		2.3	.006		60	1 S/M		
	366 Film Viewing Equipment	1/2	10%	3.57	1.43	Repl.	30D	.45	.003	Inspect and clean	20 30	1 E/E 1 E/E		
	367 EVA Backpack	3/12	1%	21.43*	5.24	Repl.		13.6	.06	▷1	20	1 L/E		
	368 Spacesuit Assy.	3/12	1%	50	15	Repl.		9.1	.09		20	1 L/E		
						or Repair		.45	.003	▷1	40	1 L/E	27	

REMARKS:

* Failure rate for backpack does not include communications equipment.

▷1 The backpack & spacesuit are checked out before and after each use. The time required for this is included in the maintenance task time whenever they are used. Some suit repair by sewing and patching or replacing disconnect seals may be performed.

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

SUBSYSTEM NOMENCLATURE	MAJOR ASSEMBLIES & COMPONENTS	NUMBER REQUIRED NORL/OLF	PERCENT OPER. TIME	FAILURE RATE OF EACH ITEM (HRS/10^{-6})	TOTAL FAILURE RATES (HRS/10^{-6})	MAINTENANCE FUNCTION REPL. REPR.	MAINTENANCE FUNCTION SERV-ICING	SPARES WEIGHT KG	SPARES VOLUME M^3	MAINTENANCE DESCRIPTION	REPAIR TIME MIN.	SKILL	TOOLS	SPECIAL CONDITIONING
Repressurization System	382 Tank, GO_2, Bays	0/2		.036	.071	Repl.		*135	.03	1	170	1 L/E	2, 9	All of the parts on this sheet are in 3.5 psia bays
	383 Tank, GO_2, hab, dock	0/1		.036	.036			* 54	.13					
	384 Tank, GO_2, hab, storeroom	0/1		.036	.036			* 39	.11					
	385 Tank, GO_2, hab, terminal	0/1		.036	.036			* 72	.17					
	386 Tank, GN_2, bays	0/2		.036	.071			* 88	.45					
	387 Tank, GN_2, hab, dock	0/1		.036	.036			* 35	4.2					
	388 Tank, GN_2, hab, storeroom	0/1		.036	.036			* 26	.14					
	389 Tank, GN_2, hab terminal	0/1		.036	.036			* 47	.25		170	1 L/E & 1 S/M		
	390 Coupling	0/10		.014	.14			.18	.0006		80	1 L/E	2, 9	
	391 Valve, shutoff, solenoid	0/10		1.43	14.3			.14	.0011		100	1 L/E		
	392 Pressure reducer	0/20		1.43	28.57	Repl.		.36	.0006		100	1 L/E	2, 11	
Oxygen Regeneration System	398 CO Reduction reactor	1/2		2.0	4.0	Repl	30D	36	.034	Replace reactor (unscheduled) Service reactor with catalyst and replace carbon filter every 30 days (45 min ea.)	120 90	1 L/E & 1 S/M 1 L/E	18, 26	Maintenance on items 398 thru 401 require working in 3.5 psia environment with auxiliary O_2 equipment
	399 Stainless steel carbon filters	2/4		.3	1.2	Repl.		3.6	.009		120	1 L/E	26	
	400 Expendable carbon filter	1/2		.3	.6	Repl	30D	3.6	.009	Replace filter assembly (unscheduled) Service at same time as reactor with which time is included	100	1 L/E	26	
	401 Electrolysis unit	1/2		.5	1.0	Repl.		16	.004		140	1 L/E	18, 26	
	402 Compressor (blower)	1/2		1.5	3.0			2.3	.003		90	1 L/E		
	403 Condenser separator	1/2		.04	.08			1.4	.0014		100	1 L/E		
	404 Heat exchanger	1/2		.07	.14			3.6	.021		100	1 L/E		
	405 Check valves	4/8		.03	.24			.14	.0014		80	1 L/E		
	406 Diverter valves	3/6		.10	.60	Repl.		.45	.002		90	1 L/E		
	407 Instrumentation & controls	1/2		1.0	2.0	Repair		.45	.003	Repair by replacing individual components	70	1 L/E		

REMARKS: 1 General scheduled maintenance — OLF
Daily - 10 min - check tank quantities & pressures

Resupply (90 days) - service all GO_2 & GN_2 tanks, 100 min. for 10 tanks at 10 min each.

* Tanks will not be spared initially, if spare tank is required, it will be brought at next resupply.

Figure 4.2-11: OLF MAINTENANCE ANALYSIS (CONT'D)

4.3 CREW REQUIREMENTS

The objective of this part of the study was to determine how many people of which skills will be required to assemble and ready the OLF for orbital launch operations and to sustain it during OLO and other orbital operations. Detailed analysis of facilities and equipment required to support the crew were performed primarily as part of the OLF on-board systems studies and are, therefore, discussed in Paragraph 5.4.6, Crew Support.

The determination of detailed crew activities and task time requirements, and the identification of the skills necessary for performing the various tasks required in the major events of the OLF mission, were accomplished in the function and task analysis of the operations studies (see Figures 4.1-5 and 4.1-11. This information comprised the basic inputs to the crew requirements analysis, which then consisted primarily of:

a. Crew utilization studies, based upon assumed allocations of time for work, rest, personal hygiene, recreation, and nutrition;

b. Analysis of specific crew skill requirements and associated training requirements;

c. Selection of crew size and composition and definition of OLF design criteria established by the requirements of the selected crew;

d. Evaluation of crew requirement perturbations expected from including R&D and scientific activities on board the OLF.

4.3.1 OLF Proper Crew Requirements. - Considering the personnel activities required in each of the four phases of operation, i. e., (1) prelaunch; (2) launch, orbital assembly and checkout; (3) orbital launch operations; and (4) scientific and R&D operations, it appears that the only significant requirements imposed upon the OLF crew by the prelaunch phase, and even the launch portion of the second phase of operation, are the flight commander or pilot capabilities. In the prelaunch activities on the pad, it is expected that at least two members of the crew will be involved in the final checkout and countdown just prior to launch. These people must be thoroughly familiar with the Apollo spacecraft systems, as well as the booster propulsion control systems in the spacecraft. No further consideration was given to prelaunch phase activities in this regard.

The primary factors influencing the composition of the crew of the OLF proper arise in the second and third phases of operation, particularly with regard to orbital launch operations applications of the OLF. The analyses of these two phases with respect to their particular crew requirements are discussed in the following paragraphs. Variations in or additions to the crew requirements, which might be expected by adding scientific and R&D activities to the OLF operation are discussed in Sections 4.3.4 and 6.2, although the routine OLF operations during phases 3 and 4 are considered identical.

4.3.1.1 Launch, Orbital Assembly and Checkout. - Work activities requirements for this phase of the OLF operation were defined in Section 4.1. In that section, the major events required to place the facility into orbit and prepare it for useful operation were defined. A function and task analysis (also described in Section 4.1) was then accomplished for the baseline OLF to identify the individual tasks required to accomplish the specified major events. For each task, manpower, skills, and time estimates were made, the details of which are shown in Figure 4.1-11 and summarized in Figure 4.1-12 of Section 4.1. The function and task analysis considered only the work anticipated and the number of people required to accomplish each task, with only secondary thought given to crew utilization and scheduling.

The next step, then, was to perform a time-line analysis of these operations to determine a feasible schedule of crew activities, allowing time for rest, nutrition and personal hygiene. Operations analysis and crew utilization studies for this phase of the operation have assumed the OLF to be an operational system, i. e., no OLF RDT&E activities in orbit and on board the OLF have been considered in this portion of the study. However, it was recognized that some such activity will be required to make the initial OLF operational and this was studied as part of the RDT&E program and is discussed in Section 7.1. The primary goal in this phase of the time-line analysis was to schedule the crew activities in such a manner that the OLF would be made ready for orbital launch operations as soon as possible after Earth launch and with a minimum expenditure of manpower.

Inasmuch as several of the tasks in this phase either require, or can best be accomplished by simultaneous use of five crewmen, a crew size of five was selected for the initial time-line analyses. Crew time distribution assumptions are listed in Figure 4.3-1 for both "normal" and "high activity" schedules.

FIGURE 4.3-1 ASSUMED CREW-TIME DISTRIBUTION

	Normal Schedule (hrs/day)	High-Activity Schedule (hrs/day)
Sleep	8.0	7.0 (2 x 3.5)
Personal Care	1.5	1.5
Nutrition	2.5	2.5
Relaxation-Exercise	1.0	1.5
-Leisure	1.0	
Work	10.0	11.5
	24.0	24.0

The total work required in this phase was estimated at about 106 man-hours. For a five-man crew, allowing some contingency for scheduling, the elapsed time required for this phase of operation using a "normal" schedule, would be between two and three days. For this brief period of time, it was decided that the crew could utilize a "high activity" schedule, to accomplish the necessary work in as short a time as possible. As shown in Figure 4.3-1, the change in working time allocation from 10 hours on a "normal" duty schedule to 11.5 hours on a "high activity" schedule was accomplished by decreasing the relaxation time by 0.5 hour and the total sleeping time by 1.0 hour. During the "high activity" period, it was also concluded that dividing the sleeping time into two periods of 3.5 hours each would provide sufficient rest in instances, where scheduling 7.0 hours of continuous sleep might require unnecessary waiting or standby of other crew members. In addition to the above assumptions, other ground rules used in the launch, orbital assembly, and checkout operations, time-line analysis included:

a. At least one 3.5-hour rest period will be allowed during each 12-hour period.

b. The OLF operations console will be manned by at least one man continuously throughout this phase of the operation.

c. No allowance for experimentation will be considered in this study for this phase of the OLF operation.

d. Biomedical monitoring of the crew members will be accomplished only to the extent determined necessary in earlier MORL or other orbital research laboratory tests.

e. Crewmen required to operate in the 3.5 psi "shirtsleeve/oxygen-mask" environment must prebreathe 100% oxygen for at least 30 minutes before transferring into that environment to prevent bends. These crewmen must also wear spacesuits without helmets and gloves until permanent sealing of those compartments is assured. Helmets and gloves must be immediately available during these activities.

f. Assumed times for pre- and post-extravehicular activities are as follows:

Don & checkout spacesuit & backpack -	10 minutes
Egress through airlock (conserving atmosphere)	16 minutes
Ingress through airlock	6 minutes
Suit & backpack removal, checkout & service	20 minutes

g. All extravehicular activities or activity within the "shirtsleeve/oxygen-mask" environment of the OLF will be continuously monitored directly or by TV. Such activities will always involve a minimum of 2 crewmen appropriately equipped and working together to accomplish the tasks.

h. Working time requirements in a hardened spacesuit will be assumed to be 35% greater than required on Earth without a spacesuit, due to added effort required to counter-pressure forces and because of associated complications in locomotion, tethering, etc.

Sheets 1 and 2 of Figure 4.3-2 present the time-line schedules developed for the launch, orbital assembly, and checkout phase of the OLF operation. The legend of line coding and location indicators in the upper-right corner of each page is

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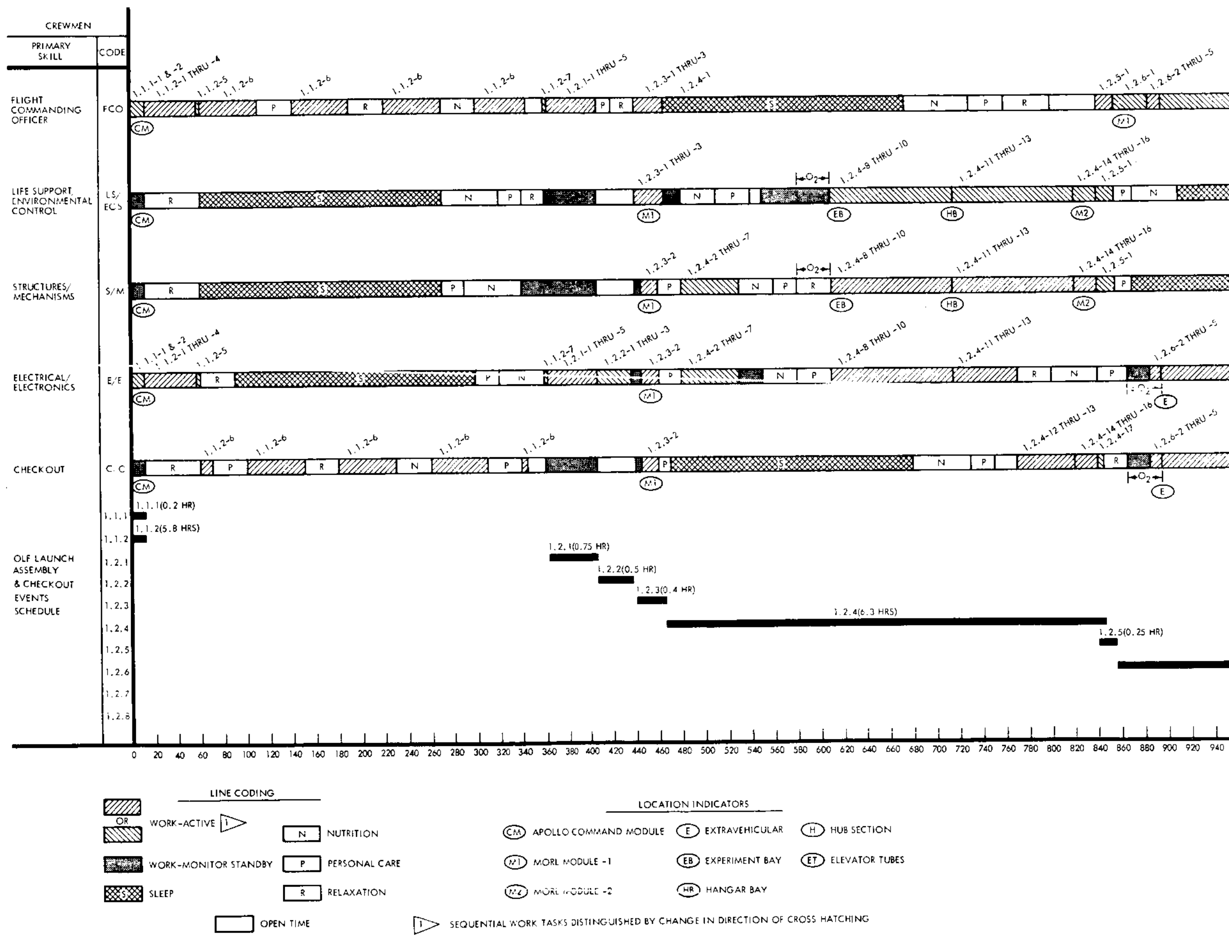
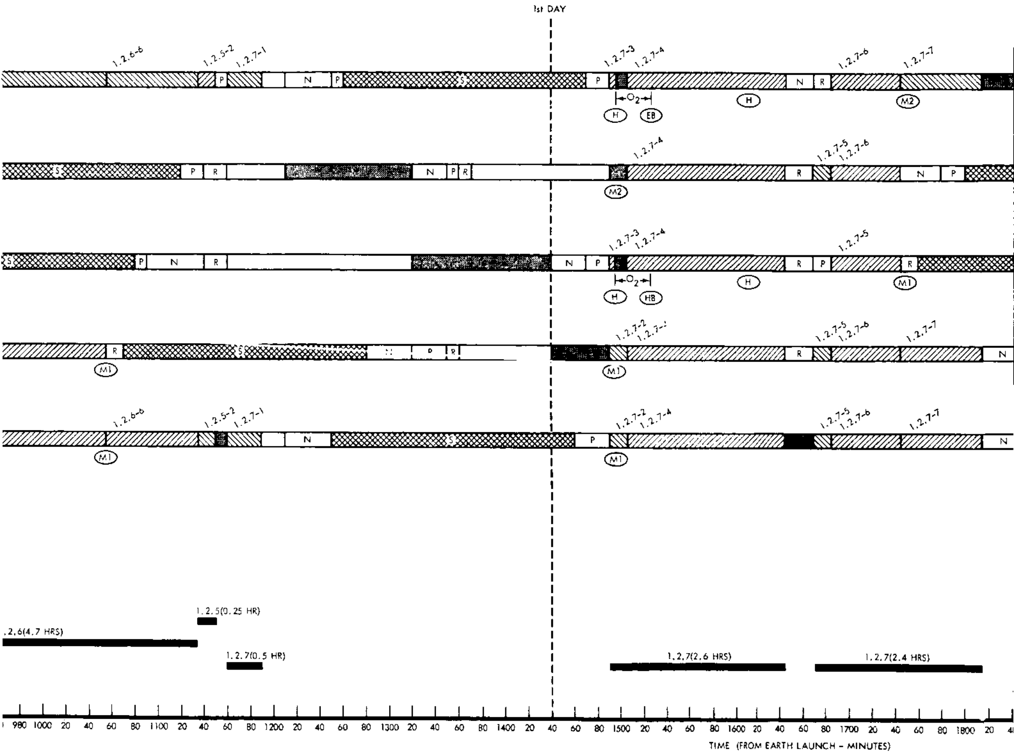
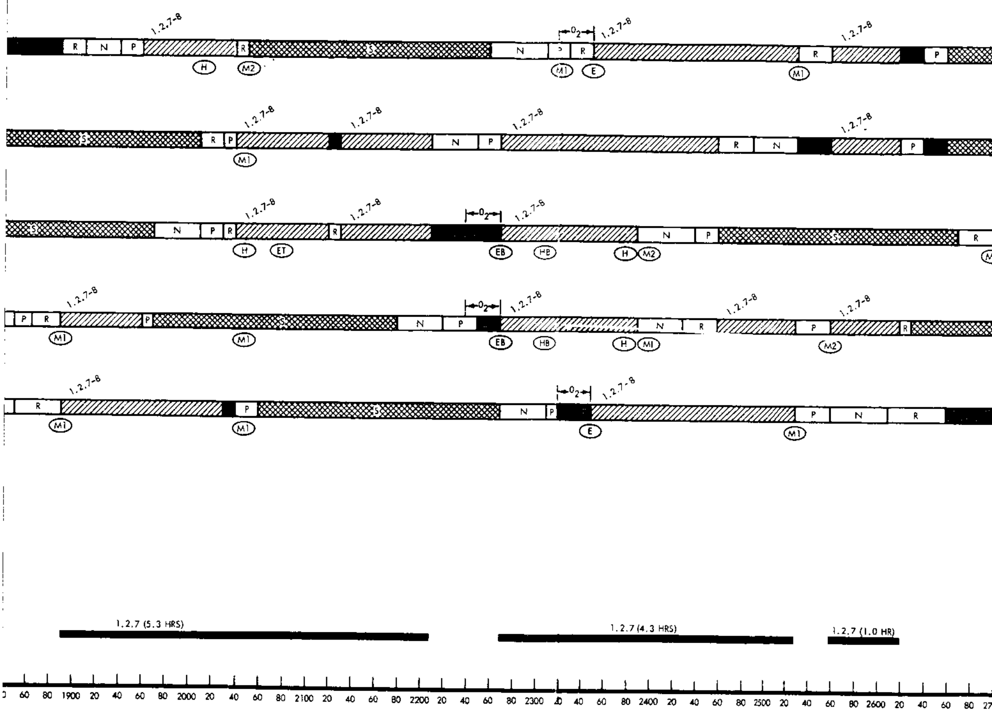


CREWMEN
PRIMARY SKILL
CODE
FLIGHT COMMANDING OFFICER
FCO
LIFE SUPPORT ENVIRONMENTAL CONTROL
LS/ECS
STRUCTURES/MECHANISMS
S/M
ELECTRICAL/ELECTRONICS
E/E
CHECKOUT
C.C
OLF LAUNCH ASSEMBLY & CHECKOUT EVENTS SCHEDULE
1.1.1(0.2 HR)
1.1.2(5.8 HRS)
1.2.1(0.75 HR)
1.2.2(0.5 HR)
1.2.3(0.4 HR)
1.2.4(6.3 HRS)
1.2.5(0.25 HR)
LINE CODING
WORK-ACTIVE
WORK-MONITOR STANDBY
SLEEP
NUTRITION
PERSONAL CARE
RELAXATION
OPEN TIME
LOCATION INDICATORS
APOLLO COMMAND MODULE
MORL MODULE -1
MORL MODULE -2
EXTRAVEHICULAR
EXPERIMENT BAY
HANGAR BAY
HUB SECTION
ELEVATOR TUBES
SEQUENTIAL WORK TASKS DISTINGUISHED BY CHANGE IN DIRECTION OF CROSS HATCHING



1st DAY
1.2.6-6
1.2.5-2
1.2.7-1
1.2.7-3
1.2.7-4
1.2.7-5
1.2.7-6
1.2.7-7
1.2.7-2
N
P
R
S
H
EB
HB
M1
M2
O_2
1.2.6(4.7 HRS)
1.2.5(0.25 HR)
1.2.7(0.5 HR)
1.2.7(2.6 HRS)
1.2.7(2.4 HRS)
980 1000 20 40 60 80 1100 20 40 60 80 1200 20 40 60 80 1300 20 40 60 80 1400 20 40 60 80 1500 20 40 60 80 1600 20 40 60 80 1700 20 40 60 80 1800 20
TIME (FROM EARTH LAUNCH - MINUTES)

2



3

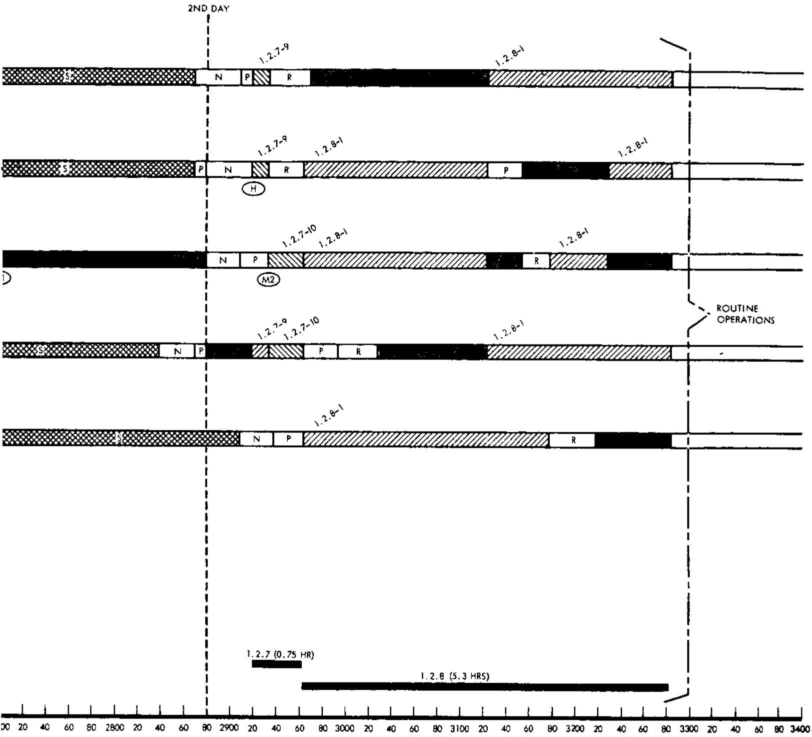


Figure 4.3-2: CREW UTILIZATION TIME LINE ANALYSIS ASSEMBLY AND CHECKOUT

4

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self-explanatory. The numbers appearing diagonally above the work blocks in each crewman's schedule designate the particular task being accomplished. The task numbers correspond with those identified in the function and task analysis of Figure 4.1-11 of Section 4.1. The general location of each crew member is shown initially by a location indicator appearing just below the first event in each crewman's line schedule. Whenever there is a change in the crewman's general location, the appropriate new location indicator is placed below the line at the time the relocation is affected. Along the lower part of each sheet is a major event schedule showing the periods during which each event is accomplished and giving the elapsed time required by each event. Figure 4.3-3 summarizes the active working time assigned to each of the five crewmen for accomplishing the ten major events of this phase of OLF operation. The job assignments were made according to primary, secondary, and general skills of each crew member. Skills and training are discussed in later paragraphs. Figure 4.3-4 presents an overall summary of each crewmember's time utilization as set forth in the time-line of Figure 4.3-2. About 49 percent of the available crew time is utilized in active and standby work. "Active" work is herein defined as that work which is directly involved with the accomplishment of the established work tasks, and includes the associated console operation or monitoring. Standby work is primarily routine console monitoring when such activity is not a direct part of the work tasks. It is also interesting to note that in the final iteration of the time-line analysis, the "open" time (i. e., unscheduled crew time) resulting from the activity scheduling amounted to 3.8 percent. Through most of the time-line iterations, the open time varied between 3 and 5 percent. In this analysis, then, the total scheduled crew time amounted to 96.2 percent of the total available man-hours during the 54.7 hours required to accomplish this phase of operation.

Assuming the same percentage crew utilization could be attained using a 4-man crew (this requires no percentage increase in standby work nor unscheduled time), the minimum time required to accomplish this phase would be about 70 hours, an increase of nearly 30 percent in the total elapsed time. The assumptions made here are unrealistic, however, because of the sequential nature of the work, i. e., one task being dependent upon the completion of the previous task. The standby work time of a 4-man crew would probably be considerably more, particularly in the activation and checkout work where the checkout of similar or related systems in different areas of the OLF can be accomplished simultaneously if an adequate number of people are available. However, even within the above assumptions, the total man-hours required to complete the phase would be 280 for a 4-man crew compared to about 274 for the 5-man crew. It is felt that in a detailed scheduling for a 4-man crew, the time requirement would prove to be even greater. Likewise, in the addition of more people, such as providing a crew of 6 people, the unscheduled or "open" time is expected to increase sharply. Therefore, within the depth of this analysis, the 5-man crew appears to be the most feasible crew size for the launch, orbital assembly, and checkout phase of the OLF operations.

The particular crew skill requirements for this phase of the operation are itemized by man-hours of active work required in each skill category in Figure 4.1-12, Paragraph 4.1. After combining related skills, the skills required, in order of decreasing man-hour requirements, are: structural/mechanical; checkout/console operation; flight comand; general; environmental control (including life support); and electronic/electrical. These skills are more logically discussed with respect to the integrated OLF crew requirements, therefore, detailed des-

LAUNCH, ORBITAL ASSEMBLY & CHECKOUT OPERATION											
	Man-hours per Major Event										
	1.1.1	1.1.2	1.2.1	1.2.2	1.2.3	1.2.4	1.2.5	1.2.6	1.2.7	1.2.8	
MAJOR EVENTS / Description / CREWMAN	Launch & Inj. into Transfer Orbit	Transfer & Inj. into 535 km Orbit	Separation & Redocking of Apollo CM	Remote Activation of MORL LSS & ECS	Crew Transfer to MORL Module 1	Extension of MORL Modules 1 and 2	Deployment of Antennas & Activation of Comm. & Tracking	Assembly & De-orbit of Inj. Stage/CM Fair.	Activation & Checkout of all OLF Systems	Repairs	TOTAL MAN-HOURS ACTIVE WORK ASSIGNED
FLIGHT COMMANDER (FCO)	0.20	4.08	0.75	--	0.41	--	0.50	4.67	10.67	2.67	23.95
LIFE SUPPORT & ENVIRONMENTAL CONTROL SYSTEMS (LS/ECS)	--	--	--	--	0.42	3.83	0.25	--	10.67	3.58	18.75
STRUCTURAL & MECHANICAL (S/M)	--	--	--	--	0.25	4.67	0.25	--	8.58	3.50	17.25
ELECTRICAL & ELECTRONICS (E/E)	0.20	0.84	0.75	0.50	0.25	3.50	--	2.83	11.08	2.67	22.62
CHECKOUT (C/O)	--	2.75	--	--	0.25	1.25	0.25	4.17	10.83	3.58	23.08
TOTAL MAN-HOURS PER EVENT	0.40	7.67	1.50	0.50	1.58	13.25	1.25	11.67	51.83	16.00	105.65

* FCO is involved in this activity only on a semi-alert basis, therefore, his time can be otherwise utilized as long as he remains in immediate vicinity of control panel.

Figure 4.3-3: CREW WORK ASSIGNMENT SUMMARY

CREWMAN	SCHEDULED CREW TIME -- MANHOURS						OPEN TIME	TOTALS
	WORK TIME		SLEEP	NUTRITION	PERSONAL CARE	RELAXATION		
	ACTIVE	STANDBY						
FLIGHT COMMANDER (FCO)	23.95	4.33	14.00	4.50	3.05	3.67	1.25	54.75
LIFE SUPPORT & ENVIRON. CONTROL (LS/ECS)	18.75	6.57	14.00	5.08	3.42	3.38	3.55	54.75
STRUCTURAL & MECHANICAL (S/M)	17.25	9.32	14.00	4.67	3.08	3.55	2.88	54.75
ELECTRICAL & ELECTRONICS (E/E)	22.62	4.22	14.00	4.92	3.83	3.83	1.33	54.75
CHECKOUT C/O)	23.08	4.40	14.00	4.58	3.42	3.80	1.47	54.75
GRAND TOTALS	105.65	28.84	70.00	23.75	16.80	18.23	10.48	273.75
PERCENT OF AVAILABLE TIME	38.6	10.5	25.6	8.7	6.1	6.7	3.8	100.00

Figure 4.3-4: CREW UTILIZATION SUMMARY

criptions and discussions are presented in Paragraph 4.3.2. It should be noted here, however, that the level of proficiency required of most of the above skills is more of a "technician" level, which might be considered somewhat lower than that required for problem analysis, maintenance, and repair. This is also discussed further in the following sections.

4.3.1.2 OLF Routine Operations During and After Orbital Launch Operations. - Activities of the OLF during orbital launch operations, as defined in the operational studies of Section 4.1.1, are described as routine operations, consisting basically of station operations, personnel operations, and maintenance operations. Figure 4.1-14 of Section 4.1 further identifies the activities included in each of those categories. The detailed function and task analysis sheets for the station and personnel operations are presented in Figure 4.1-15 of Paragraph 4.1. Detailed analysis of maintenance operations is discussed in Paragraph 4.2. Figure 4.1-16 of Section 4.1 summarizes the manhour and skill requirements for the station operations over a 90-day period, while Figure 4.2-10 of Paragraph 4.2 summarizes the manhour and skill requirements of the maintenance of the OLF proper, as well as the integrated OLO maintenance required of the OLF. The station operations and maintenance operations, as defined in this study, are essentially independent of the number of people in the OLF crew, whereas, the personnel operations man-hour requirement for the entire routine operations is dependent upon the crew size assumed. Figures 4.1-17, -18, and -19 of Paragraph 4.1, summarize these requirements for an assumed 4-man or 5-man crew.

Manpower utilization curves, for varying crew sizes, have been developed for the OLF routine operations and are presented in Figure 4.3-5 . These curves are based on the function and task analysis of the routine operations and on the maintenance analysis of Paragraph 4.2, which have given little consideration to activity scheduling other than sequentially ordering the tasks as required. Hence, the total OLF routine operations curves could be considered ideal; i. e., no allowance has been made for "open" or unscheduled time that inevitably occurs in long-term scheduling. From 3 to 5 percent "open" time occurred in iterations of the 55-hour launch, orbital assembly, and checkout phase schedule. It is evident from the curves of Figure 4.3-5, that a crew size of 4 is the minimum size crew that could perform the routine operation within a "normal activity" schedule. It can be assumed that because of the differing schedule periods (i. e., daily, weekly, monthly, 90-day, and yearly) uniform scheduling of the work throughout the year will probably be impossible. Probably a "high activity" work schedule will also be required for short periods of time. It is also expected that there will be days of less scheduled work and more "open" time than indicated for average crew utilization as shown in Figure 4.3-5. Utilization percentages for the 4 and 5-man crews are predicted at about 94 and 88 percent respectively.

From the standpoint of operating the OLF in support of orbital launch operations, a minimum crew size of 4 men appears feasible. If additional operational requirements are imposed upon the crew, larger crew size appears mandatory unless higher activity schedules for extended periods prove to be acceptable. For an OLF crew size of 4 men, a time-line schedule of a typical "busy" day of routine operations is presented in Figure 4.3-6. Crew utilization for that 24-hour period is about 98.3 percent, with only about 1.7 percent "open" time. The maintenance work shown was arbitrarily assigned, with no consideration given to specific tasks. Figure 4.3-7 presents a numerical summary of crew operations

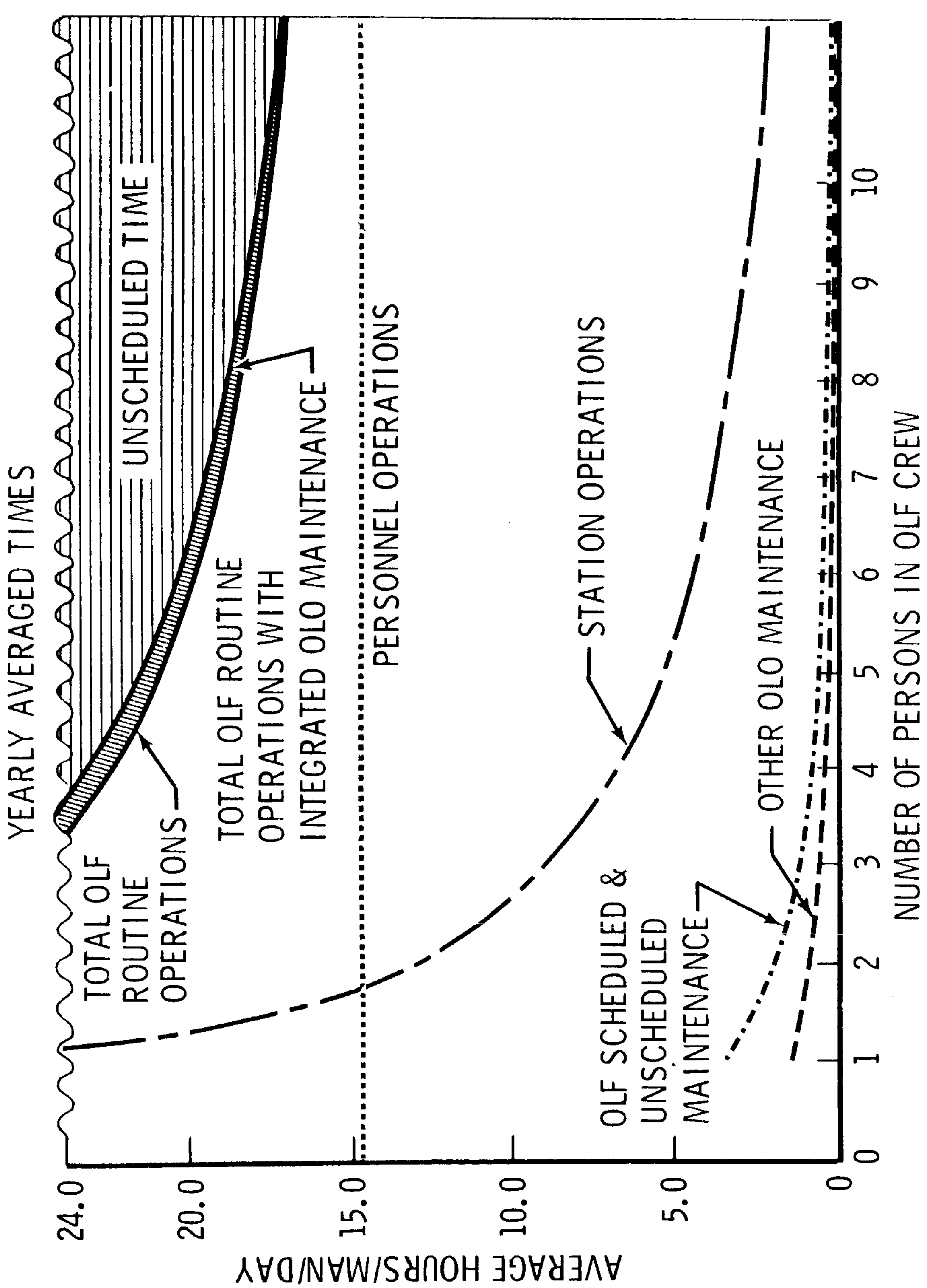
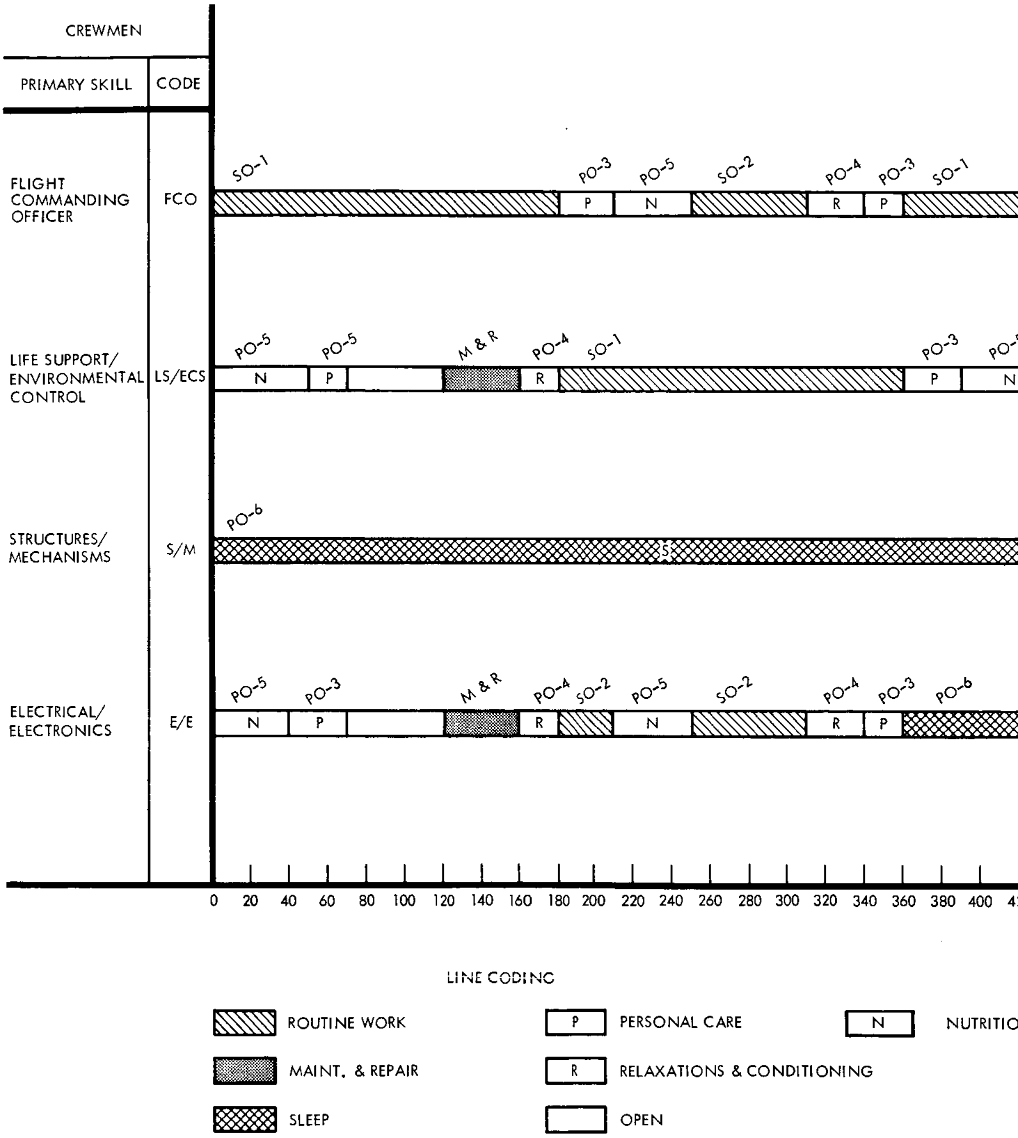
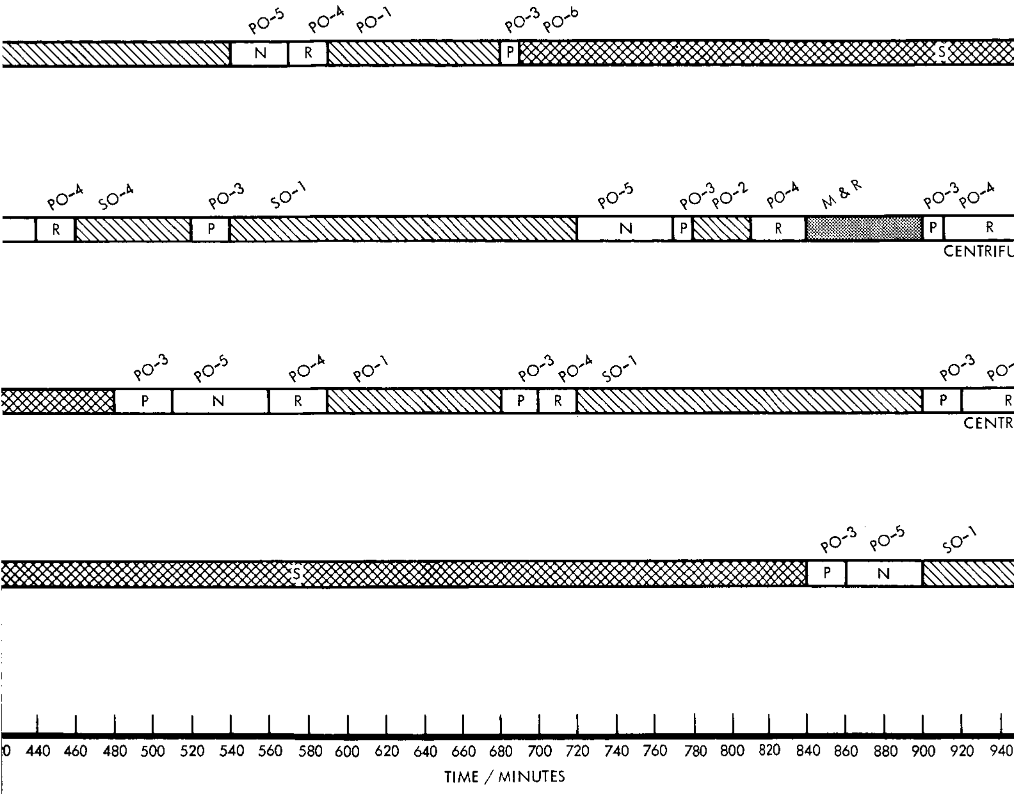


Figure 4.3-5: OLF ROUTINE OPERATIONS - MANPOWER UTILIZATION


CREWMEN
PRIMARY SKILL
CODE
FLIGHT COMMANDING OFFICER
FCO
SO-1
PO-3
PO-5
SO-2
PO-4
PO-3
SO-1
P
N
R
P
LIFE SUPPORT/ ENVIRONMENTAL CONTROL
LS/ECS
PO-5
PO-5
M & R
PO-4
SO-1
PO-3
N
P
R
P
N
STRUCTURES/ MECHANISMS
S/M
PO-6
S
ELECTRICAL/ ELECTRONICS
E/E
PO-5
PO-3
M & R
PO-4
SO-2
PO-5
SO-2
PO-4
PO-3
PO-6
N
P
R
N
R
P
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400
LINE CODING
ROUTINE WORK
MAINT. & REPAIR
SLEEP
P
PERSONAL CARE
R
RELAXATIONS & CONDITIONING
OPEN
N



PO-5
PO-4
PO-1
PO-3
PO-6
N
R
P
S
PO-4
SO-4
PO-3
SO-1
PO-5
PO-3
PO-2
PO-4
M & R
PO-3
PO-4
R
P
N
R
P
R
CENTRIFU
PO-3
PO-5
PO-4
PO-1
PO-3
PO-4
SO-1
PO-3
P
N
R
P
R
P
R
CENTR
S
PO-3
PO-5
SO-1
P
N
440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740 760 780 800 820 840 860 880 900 920 940
TIME / MINUTES

CREW MEMBER	EVENT MAN-HOUR UTILIZATION													
	STATION OPERATIONS					PERSONNEL OPERATIONS						M & R	OPEN	TOTAL TIME PER CREW MEMBER
	Systems Monitoring	Navigation Attitude & Orbit Control	Logistics Operation at OLF	Gen'l. Station Housekeeping	Artificial Gravity	Crew Condition Assessment	Crew Training & Emergency Drills Ops.	Personal Care	Relaxation and Conditioning	Nutrition	Sleep			
FCO	6.0	1.0	--	0.8	--	1.5	--	1.5	2.0	2.5	8.0	0.7	--	24.0
LS/ECS	6.0	--	--	1.0	--	--	0.5	1.5	2.0	2.5	8.0	1.7	0.8	24.0
S/M	6.0	--	--	1.0	--	1.5	0.5	1.5	2.0	2.5	8.0	1.0	--	24.0
E/E	6.0	1.5	--	--	--	--	--	1.5	2.0	2.5	8.0	1.7	0.8	24.0
	24.0	2.5	--	2.8	--	3.0	1.0	6.0	8.0	10.0	32.0	5.0	1.6	96.0

Figure 4.3-7: 4 MAN CREW ROUTINE OPERATIONS TYPICAL 24 HOURS

assignments for the 24-hour period scheduled in Figure 4.3-6.

The basic assumptions used in this analysis of routine operations are as follows:

a. The crew will, over the long term of the mission, maintain insofar as possible, the "normal" activity schedule shown in Figure 4.3-1, with 8.0 hours of continuous sleep.

b. The OLF operations console will be monitored 24 hours per day; i. e., at least one crew member must always be within immediate access of the console and make periodic assessment of the panel instrumentation.

c. Experimentation activities will not be considered part of OLF routine operations in this analysis.

d. Biomedical monitoring of the crew members will be accomplished to the extent determined necessary by earlier orbital research.

e. Crewmen operating in the 3.5 psi "shirtsleeve/oxygen mask" environment, must prebreathe 100% oxygen for at least 30 minutes before entering that environment.

f. Extravehicular and spacesuit activity assumptions are same as for the launch, orbital assembly and checkout phase of the OLF operation.

The crew skills for routine operations are discussed in more detail in Paragraph 4.3.2, however, it may be pointed out here that the predominant factor in establishing the crew skill requirements for this phase of the operation, was the maintenance work requirements.

4.3.2 Integrated Crew Selection, Skills and Training. -- The following paragraphs describe the analysis made of skills and training requirements for an integrated OLF crew; i. e., a crew that can perform the functions required in all phases of operation of the OLF proper. The extent of this study did not allow a very detailed analysis, therefore, the objectives established for this part of the study were to determine, generally, the skills required in each phase of operation to select a functional OLF crew in terms of number of people and skill composition, to provide reasonable estimates of the comparative level of proficiency required in each skill, and to postulate the training that might be required.

4.3.2.1 Skill Requirements. -- As mentioned previously, the only significant skill requirements imposed upon the OLF crew by the prelaunch phase of the mission are considered to be flight commander and console operation skills. Phases 2 and 3 (launch, orbital assembly, & checkout, and orbital launch operations -- routine OLF operations) offer the primary crew requirements. Phase 4, scientific and R&D operations, presents additional requirements if the crew were required to perform those operations as well as the routine OLF operations; however, the requirements imposed by Phase 4 are discussed separately in Paragraph 4.3.4. The primary skill requirements of each of the first three phases are summarized in Figure 4.3-8 by percentage of the total time required by each skill.

FIGURE 4.3-8 OLF SKILL REQUIREMENTS SUMMARY

SKILLS	PERCENT OF TIME FOR EACH PHASE		
	Phase 1	Phase 2	Phase 3
Flight Command	)Primary skills)required of)this phase	4.6	0.7
Console Operation & Checkout		17.9	25.0
Life Support & Environmental Control		5.2	2.9
Mechanical		7.1)) 12.9	0.9
Structural		5.8)	
Electrical/Electronic		3.1	1.5
General		56.3	69.0
		100.0	100.0

The skills listed in the above table have been defined for this study as follows:

Flight Command. - The capability of checking out, monitoring, analyzing performance and controlling (where applicable) Apollo Command Module systems, S-II stage and injection stage propulsion and guidance systems, and OLF stabilization and orbit correction systems. The capability of interpreting flight data and navigating and controlling the OLF through any orbital maneuvers required, as well as controlling the Apollo Command Module and remotely controlling unmanned systems in rendezvous and docking operations with the OLF, are also included in this skill requirement. General station command is also a requisite of this skill category.

Console Operation & Checkout. - The capability of checking out the operations console and checkout equipment; assessing and adjusting systems conditions and performance through console instrumentation and controls; initiating remedial action from the console for correction of malfunctions; conducting intrastation, intraorbital, and orbit-to-Earth communications and data transmissions; and activating and deactivating systems from the console as required for routine operation, maintenance, checkout and repair.

Life Support and Environmental Control. - Familiarity with the life support environmental control systems. The capability of activating and checking out these systems, analyzing their performance, correcting malfunctions, and performing the necessary scheduled and unscheduled maintenance on these systems.

Mechanical. - Familiarity with all mechanical systems on board the OLF, including deployment systems, fluid pumping systems, centrifuges, stowage arm assemblies, docking mechanisms, stabilization and orbit correction propulsion systems, umbilical servicing tower systems, cargo conveyors and equipment handling systems, and other servicing systems. The capability of activating and checking out these systems, analyzing their performance, correcting malfunctions, and performing the necessary scheduled and unscheduled maintenance.

Structural. - Familiarity with all OLF external and internal structures, joints and seals, and storage tanks. The capability of assembling and checking out these structures; analyzing and correcting structural failures; diagnosing and remedying leaking joints or seals and repairing punctured or otherwise damaged structures in emergency as well as nonemergency circumstances; performing routine scheduled inspection and maintenance to assure continued structural integrity.

Electrical/Electronics. - Familiarity with all OLF electronics and electrical systems and circuitry, including OLF electrical power generation, conditioning and distribution systems, communications, telemetry, data processing, radar and tracking aids, panel instrumentation, and electronic display systems. The capability of activating and checking out these systems, analyzing their performance and condition, and adjusting, repairing or otherwise maintaining the systems.

General. - Familiarity with all personal crew equipment; training equipment; emergency equipment and alarm systems; recreation and conditioning equipment; food storage and preparation equipment; waste collection, processing, and storage equipment; and medical equipment and station housekeeping equipment. The capability of assessing the condition and operability of the equipment and systems mentioned above; making adjustments and performing the necessary general maintenance and operating the equipment as necessary to accomplish the routine operations of the station; and performing basic operations, such as personnel and cargo transfer inside and outside of the OLF, monitoring and diagnosing basic crew physiological and psycological conditions, analyzing problems logically, making rational decisions, and exercising individual initiative in contributing to the total success of the mission.

It is readily understood that individual tasks in each of the operational phases of the missions may require differing levels of proficiency in the particular skills defined above. For example, most of the systems activation and checkout work of the second phase of operation (launch, assembly, and checkout) would probably require little more than a "technician's" level of proficiency, barring unforeseen malfunctions or serious troubles. Most of those operations would be perfomed by pushing buttons, throwing switches, and observing instruments, all in accordance with prescribed check lists. However, the scheduled, and particularly, the unscheduled maintenance of the routine operations of Phase 3, and skill requirements if troubles are encountered in Phase 2, will require a higher level of skill proficiency. In such cases, the individuals must be capable of making on-the-spot diagnosis of systems performance or malfunctions and performing remedial action, whether it be something of an anticipatory nature for which corrective action has been planned or expected malfunctions, wherein improvised repair may be necessary. The possibilities of suddenly being exposed to the hazards of the space environment through systems damage or malfunctions offer sufficient reason to assure selection of personnel who are not only highly trained in their specialties, but are good, logical thinkers, who can analyze problems, and make sound decisions in emergency as well as normal operating conditions. The fact that files of microfilmed reference data on board the OLF, as well as advisory groups of specialists on Earth, will be available for analyzing many station problems does not lessen the requirement to try to meet the emergency needs wherein these sources of assistance may not be available.

In Figure 4.3-8 the flight command and console operation and checkout skills required in Phase 1 are primarily for the final systems checkout and countdown operations prior to the Earth launch of the OLF. In Phases 2 and 3, the category of general skills imposes the greatest requirement, in that it includes nearly all of the skills required in personnel operations (crew condition assessment, conditioning, eating, personal care, mobility or transfer operations, etc.), as well as some basic requirements of other operations. The general skills, enumerated in the definition above, are skills in which all members must be trained and to a proficiency level such that most every operation will be automatic; i.e., not requiring conscious consideration. The console operation & checkout skills offer the next greatest requirement in both phases.

In Phase 2 these skills are divided, not in the skills themselves, but in the levels of proficiency required, into "active" and "standby" console operation. During "active" console operation, continuous and concentrated effort is required in accomplishing or in direct support of the assembly, activation, and checkout activities. "Standby" operation is routine monitoring, making periodic checks, but always remaining in immediate access to the console in case of troubles. These skills required in Phase 3 are primarily of the "standby" level of operation. Other skill requirement distributions are shown with the mechanical and structural skills combined in Phase 3, wherein the requirements are overlapping considerably as they are, somewhat, in Phase 2.

4.3.2.2 OLF Crew Selection and Skill Assignments. - As mentioned previously, the general skills requirements are applicable to all crew members. The flight command skill requirements of Figure 4.3-8 do not account for the overall station command and decision making authority, which must be delegated, but it is desirable that the total range of skills included therein be vested in at least two crew members, one flight commander and an assistant. For the assistant these could be considered secondary skills. Like the general skills, the console operation & checkout skills are applicable to all crew members, therefore, such training must be provided. From the standpoint of systems performance analysis and detailed systems maintenance, it is desirable to have at least one man primarily trained in each of the skill categories of life support & environmental control, mechanical & structural, and electrical & electronics. It is further desirable to have at least one other crewman secondarily trained for each of these categories.

On the basis of the above reasoning, the basic OLF crew selected and the skill assignments for each crewman are as shown in Figure 4.3-9.

FIGURE 4.3-9 OLF CREW SKILL ASSIGNMENTS

CREWMEMBER	PRIMARY SKILL	SECONDARY SKILLS	SKILLS REQ'D IN ALL CREWMEN
1. Flight Commander (FCO)	Flight Command	Structural/ Mechanical	General Skills, Console Operation & Checkout.
2. Electrical & Electronics Specialist (E/E)	Electrical/ Electronics	Assistant Flight Command	Same
3. Life Support & Environmental Control Specialist (L/S/ECS)	Life Support/ Environmental Control	Electrical/ Electronics	Same
4. Structural & Mechanical Specialist (S/M)	Structural/ Mechanical	Life Support/ Environmental Control	Same
5.* Checkout Specialist (C/O)	Systems Checkout	Life Support/ Environmental Control	Same

* 5th Crewman required in Phase 2, only 4-man crew (Nos. 1 thru 4) required in OLF routine operations of Phase 3 and after OLO.

For Phase 3 of the OLF mission, the minimum 4-man crew would consist of the first four crewmen shown in Figure 4.3- 9. The fifth crew member required in Phase 2 operations, is shown as a checkout specialist inasmuch as his primary skills can be used in the Phase 2 activation and checkout operations, as well as in the orbital launch operations, in which checkout of the OLV spacecraft and booster and the LOX tankers are prime activities. Inasmuch as life support/ environmental control skills provide the greatest specialized skill requirement of the routine operations of Phase 3 (see Figure 4.3-8), that skill was assigned the checkout specialist as his secondary skill. These assignments provide sufficient redundancy in each skill category to accomplish the OLF operations as analyzed in this study.

4.3.2.3 Crew Training. - Many of the training requirements for developing the crew skills required in the general skills category of the preceding paragraphs, will have been determined in the earlier orbital research programs. Likewise, many of the training requirements for console operation and checkout will also have been determined in those programs. There are some activities required in OLF operations that will require additional training, however, such as team participation in extravehicular maintenance, assembly, and checkout activities; transferring and working at various locations in a spinning artificial gravity station; emergency rescue and evacuation procedures; operating cargo handling equipment in zero and artificial gravity systems; structural assembly and repair operations for external and internal structures; manually controlling the OLF in attitude stabilization and orbit correction maneuvers; operation of remote manipulating equipment; crew operations in combined zero "g" and reduced pressure environments using oxygen-masks only; and special training in spin-up and spin-down operations. Most of the systems oriented specialized skills such as life support/ECS, electrical/electronic, and mechanical/structural should require little more than systems orientation operational familiarity and maintenance and repair training similar to that presently being given to the crew members of intended Gemini and Apollo systems.

The training programs will require academic training, ground-based simulator training, and possibly some orbital training. The extent of each will be determined primarily by the verification of ground simulations of orbital conditions. Additional crew training program requirements are more appropriately discussed in Paragraph 7.1.7.1 of the RDT&E plan discussions.

4.3.3 OLF Design Criteria - Crew Requirements. - The intent of this paragraph is to briefly enumerate basic OLF design criteria established by the crew requirements developed in the preceding discussions and crew operations studies of Paragraph 4.1. Most of the requirements imposed upon the OLF by crew operations can be divided into four general categories: (1) life support, (2) operational support, (3) emergency and (4) training. Each category is defined and the applicable basic criteria presented in Figure 4.3-10. Only general points of criteria are presented from which detailed facilities, systems, and mechanisms requirements were derived. The detailed criteria are presented in the applicable OLF on-board systems discussions of Paragraph 5.4. As an ex mple, the first two points of criteria in the life support category specify only basic, but primary, points of criteria; i. e., life support required for given numbers of people during certain phases of the OLF operation. To provide these requirements, man's metabolic input requirements and output expectations are estimated for the expected operational activities, the applicable environmental requirements are specified, and systems criteria developed. From the analysis of applicable systems, specifications are developed for such systems as the environmental control system, water and waste management systems, food storage and preparation systems, atmospheric contaminant control systems, and all the equipment required for personal care and conditioning. The detailed criteria for these systems, as well as their evaluation and selection, are presented under the life support and environmental control and crew support equipment discussions of Paragraph 5.4.5 and 5.4.6. Similar detailed criteria and systems evaluations, developed from other points of general criteria from Figure 4.3-10 are likewise presented in the appropriate discussions of Paragraph 4.5.

4.3.4 Crew Requirement Perturbations for R&D and Scientific Activities. - The OLF crew requirements of this analysis have been primarily directed at determining the personnel requirements for accomplishing the launch, assembly, and checkout of the facility itself and for performing the routine operations

REQUIREMENT CATEGORY	CATEGORY DEFINITION	BASIC CRITERIA
LIFE SUPPORT	Those requirements pertaining to man's existing and functioning in an orbiting space station.	1. Provide life support for 5 men during launch, assembly & checkout operations; intra- and extravehicular. 2. Provide life support for 12 people during routine or orbital launch operations on a continuous basis with 50% overload capability for a minimum of 15 days; intra- and extravehicular. 3. Provide for life support resupply. 4. Provide crew rotation every 6 months, preferably one-half every 90 days.
OPERATIONAL SUPPORT	Those requirements pertaining to putting the crewmen into orbit and equipping them to do useful work from or within the orbiting station.	1. Provide an adequate number of air locks for personnel transfer in extra- and intravehicular activities. 2. Provide personnel and cargo transfer mechanisms or equipment for locomotion within the zero-g or artificial-g station and for extravehicular activities. 3. Provide maintenance equipment, maximum maintainability and internal accessibility for OLF upkeep, minimize extravehicular maintenance.
EMERGENCY	Those requirements pertaining to emergency survival, rescue and escape in case of serious systems troubles.	1. Provide inherent protection from complete catastrophic failures through compartmentalization or other damage isolation provisions. 2. Provide continuous escape and return-to-Earth capability at the OLF for all persons aboard the facility.
TRAINING	Those requirements pertaining to man's retention of a level of skill proficiency consistent with that required for the desired operations.	1. Provide training aids applicable to the skills required, technical reference literature, mockups, etc., commensurate with the level of proficiency required and skill retention capabilities (yet to be determined). 2. Provide demonstration programs for use of the operating systems in teaching and practicing.

Figure 4.3-10: OLF DESIGN CRITERIA - CREW REQUIREMENTS

necessary to keep the facility operational throughout orbital launch operations. This analysis is equally applicable to other types of orbital operations; hence, the basic crew of 4 men (minimum) has been established. From the routine operations-manpower-utilization curves of Figure 4.3-5, it is evident that a crew size of 4 men offers little or no unscheduled time for other activities. Therefore, any additional operations on board the OLF will require additional people. If those people were integrated into the OLF crew; i. e., sharing in OLF station operating and maintenance operations, their expected time available for other activities can also be read as the "unscheduled time" from Figure 4.3-5. If the nature of the R&D or scientific activity required only about 20 to 25 man-hours of crew work per day, it would probably be advantageous to use an integrated crew, particularly if the experimentation of the basic 4-man OLF crew would allow accomplishing the total job with fewer people. However, if the experimental work were highly specialized and required many man-hours of work, the operations would probably be accomplished more effectively by not sharing station operation and experimentation duties. However, basic OLF familiarization training for the experimentation specialists should be required such that they may fill in as temporary crew members in an emergency.

Any specialized crew requirements with respect to R&D and scientific activities on board the OLF are discussed in the separate analysis of Paragraph 6.2.

4.4 SPARES & EXPENDABLES

Spares include those replaceable components which are stored in the OLF to maintain it, the checkout equipment, the orbital launch vehicle, the orbital tankers, logistic spacecraft, and orbital support equipment in an operating condition.

Expendables are those consumables subject to resupply that are either consumed directly, such as food and oxygen, or that are eventually consumed or rendered unusable by normal wear and tear. In this category are filters, personal and recreation equipment, etc.

4.4.1 Spares Philosophy. - The extended length of the OLF mission establishes the necessity for continuous maintenance and spares logistic support to assure a high probability of mission success. It has previously been determined that the logistic resupply interval would be 90 days, and that a backup logistic resupply vehicle would be available to ensure the successful completion of resupply missions at the required intervals.

The supplies to be carried in the initial launch of the OLF will be sufficient to sustain operations for 135 days, which provides a further margin of safety in case of a delay in any of the resupply launches. The initial spares loading will ensure a 99% probability of having the correct spare, when needed, for a 135-day period. The logistics resupply vehicles will carry the spares and expendables necessary to make up for those used during the previous 90 days and restore the OLF to its original capability for 135 days of operation.

The basic maintenance concept which determines the spares philosophy is one of component replacement. The OLF systems will have the capability to isolate faults to the replaceable component level. The replaceable component levels were identified in the maintenance & repair analysis, described in Paragraph 4.2, and are the components which are provided as spares. A certain amount of repair is provided for and this is also identified in the maintenance analysis. Sufficient redundancy of system components will be designed into the OLF to protect against crew safety or mission critical failures, which could not be repaired within the allowable system downtime.

Storage space will be provided in each MORL and in the bay areas for the spares. The storage volume required, because of packaging, delivery, and access requirements, is estimated to be about 50% more than the volume of the spare itself. The spares will be stored in the area nearest to the location in which they are expected to be used, and will be stored so they are readily accessible. An inventory will be kept of the spares on board and their storage location within the OLF to facilitate finding the correct spare as needed and to aid in storing new spares, which are provided at each resupply.

4.4.2 Determination of Spares. - The probability of success of the OLF is greatly influenced by the effective utilization of spares. Therefore, a major effort has been directed to achieve the maximum practicable probability of mission success for the least cost. Cost may be mass, volume, dollars, time, or any other system variable which can be measured. As mass has been chosen as the primary constraint for the OLF, this study has been primarily concerned with determining the maximum probability of mission success for the least amount of spares mass. The probability of mission success is the probability of having the correct spare on board the OLF whenever a malfunction occurs. This optimization of spares provisioning was accomplished through the use of a technique described in Boeing BSRL Document D1-82-0253, dated May 1963, entitled "Optimal Redundancy under Multiple Constraints". The basic principle of this method is that it takes a basic system design and adds spare components, one unit at a time, to achieve the maximum reliability for the least cost, in this case, mass. It does this by selecting the maximum value of R_1, which is the incremental increase in reliability per unit mass, that can be obtained by adding one component to the system as a spare. Based on the formula from which R_1 is calculated, a computerized model has been prepared which selects the spare components to be added and calculates the reliability and mass increases. For this study, the computer was also programmed to calculate the volume associated with the spares mass. Spares data is based on component failure rates contained in General Electric Report ASD-R-05-64-1, dated May 15, 1964, which were factored down to one-tenth of the values shown to reflect expected state-of-the-art growth.

4.4.3 OLF Spares Requirements. -

Initial OLF Spares. - The spares optimization method for determining the initial spares mass for 135 days for the OLF, is a function of system component reliability, mass, and volume. The determination of this data was accomplished in the OLF maintenance plan section (Paragraph 4.2).

A total of 392 different components were identified in the maintenance analysis. The reliability, mass and volume data for each of these components was fed into the computerized spares model, which calculated the increase in system reliability obtained for an optimum mass of spares. The failure rates for some of these components was adjusted as necessary to account for variations in operating time and component redundancy. Some system components which had low failure rates, adequate redundancy, or high mass were not considered in the initial spares loading. In all of these cases, the existing system is sufficiently redundant that a failure of one of these items can be tolerated until the next resupply period, which would be an average of 45 days. At the next resupply, the required spare would be brought to the OLF so the failed item could be replaced. A list of the items not considered in the initial spares loading and the predicted rate of failure is shown in Figure 4.4-1. Predicted rates of failure were obtained from the computer simulation. The resulting spares mass and volume data for increasing probabilities of mission success, i. e., probability of having correct spare when needed, were plotted in Figures 4.4-2 and 4.4-3. Note that large increases in spares mass are required for only slight improvements in probabilities of success above 99%. Figure 4.4-4 presents a breakdown by OLF systems of the mass weight and volume required for a 99.7% probability* of having the correct spare for a 135-day orbit period. An interesting statistic pointed out by this chart is that about 69% of the spares mass and 77% of the volume is taken up by spares for the environmental control system, and structures and mechanisms.

Figure 4.4-16 shows the quantity of each type of component in the OLF which

* See Table 4.4-9 for integrated system probability allocation.

is included in the initial spares loadings for a 99.7% probability of having the correct spare when needed for a 135-day period.

FIGURE 4.4-1 OLF COMPONENTS NOT IN INITIAL LOADING

ITEM NO. *	NOMENCLATURE	PREDICTED RESUPPLY REQUIREMENT
1	O_2 Subcritical Tank	0/25 yrs.
2	O_2 Subcritical Tank (Heater failure)	0/25 yrs.
4	O_2 Subcritical Tank (HX failure)	0/25 yrs.
9	N_2 Subcritical Tank	0/25 yrs.
10	N_2 Subcritical Tank (Heater failure)	0/25 yrs.
12	N_2 Subcritical Tank (HX failure)	0/25 yrs.
18	GO Tank	0/25 yrs.
21	PLSS GO $Tank_2$	0/25 yrs.
24	GN_2 Tank	0/25 yrs.
179	IMU	1/6 yr.
180	Sextant & Scanning Telescope	0/25 yrs.
181	Digital Computer	0/25 yrs.
216	Propellant Tank Assembly	0/25 yrs.
382-385	GO_2 Tanks	0/25 yrs.
386-389	GN_2 Tanks	0/25 yrs.
	* See Figure 4.4-16	

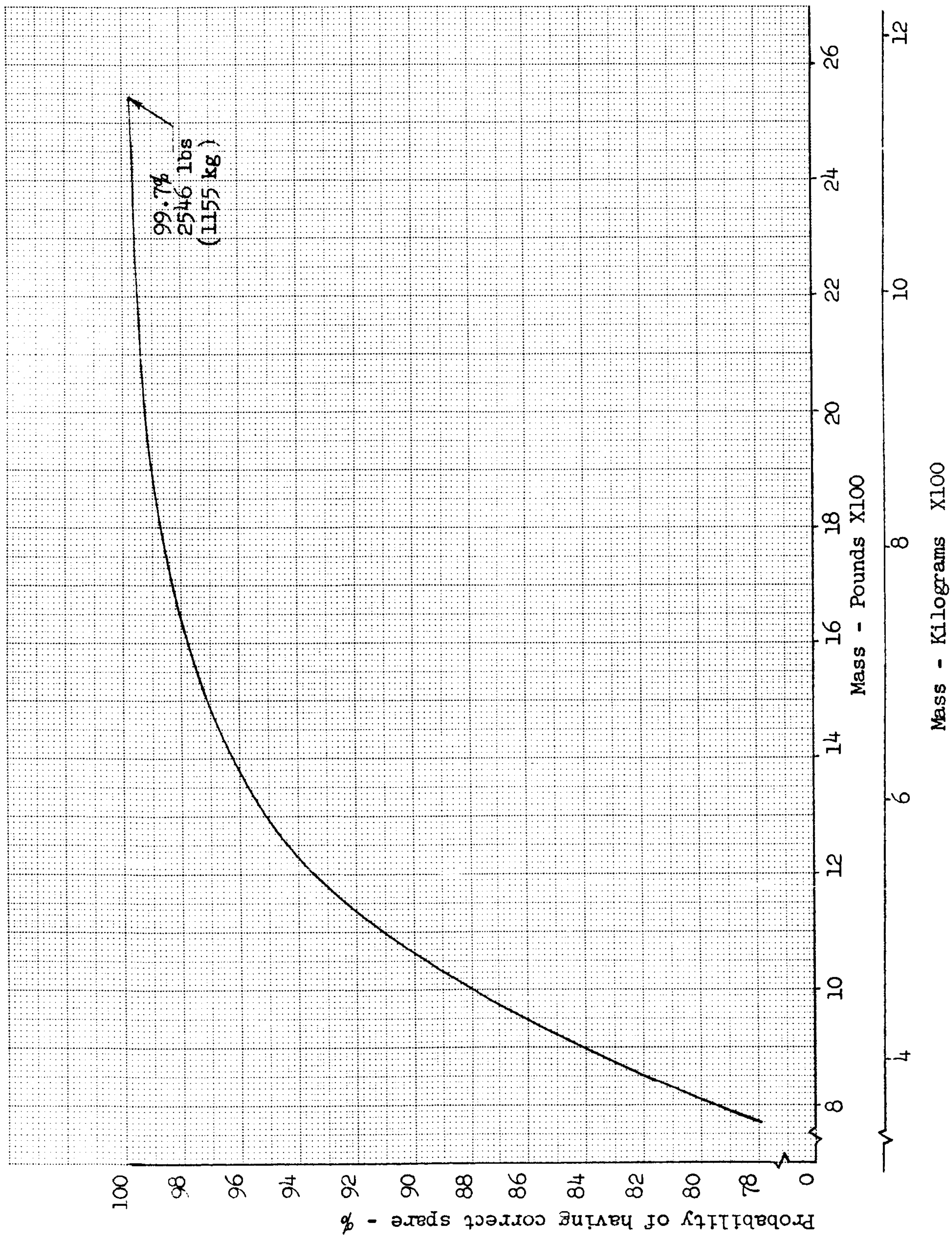


Figure 4.4-2: OLF INITIAL SPARES MASS - 135 DAYS

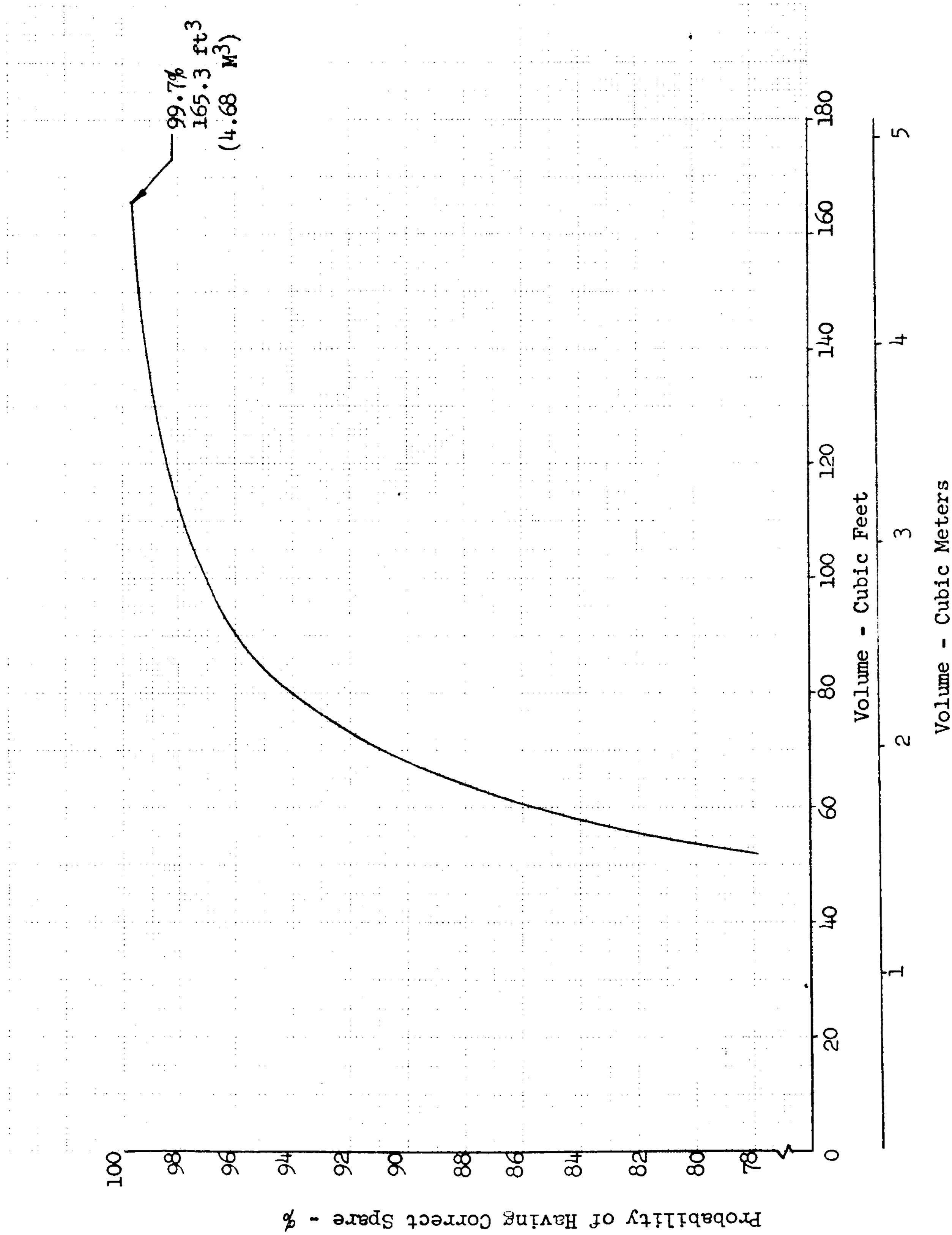


Figure 4.4-3: OLF INITIAL SPARES VOLUME

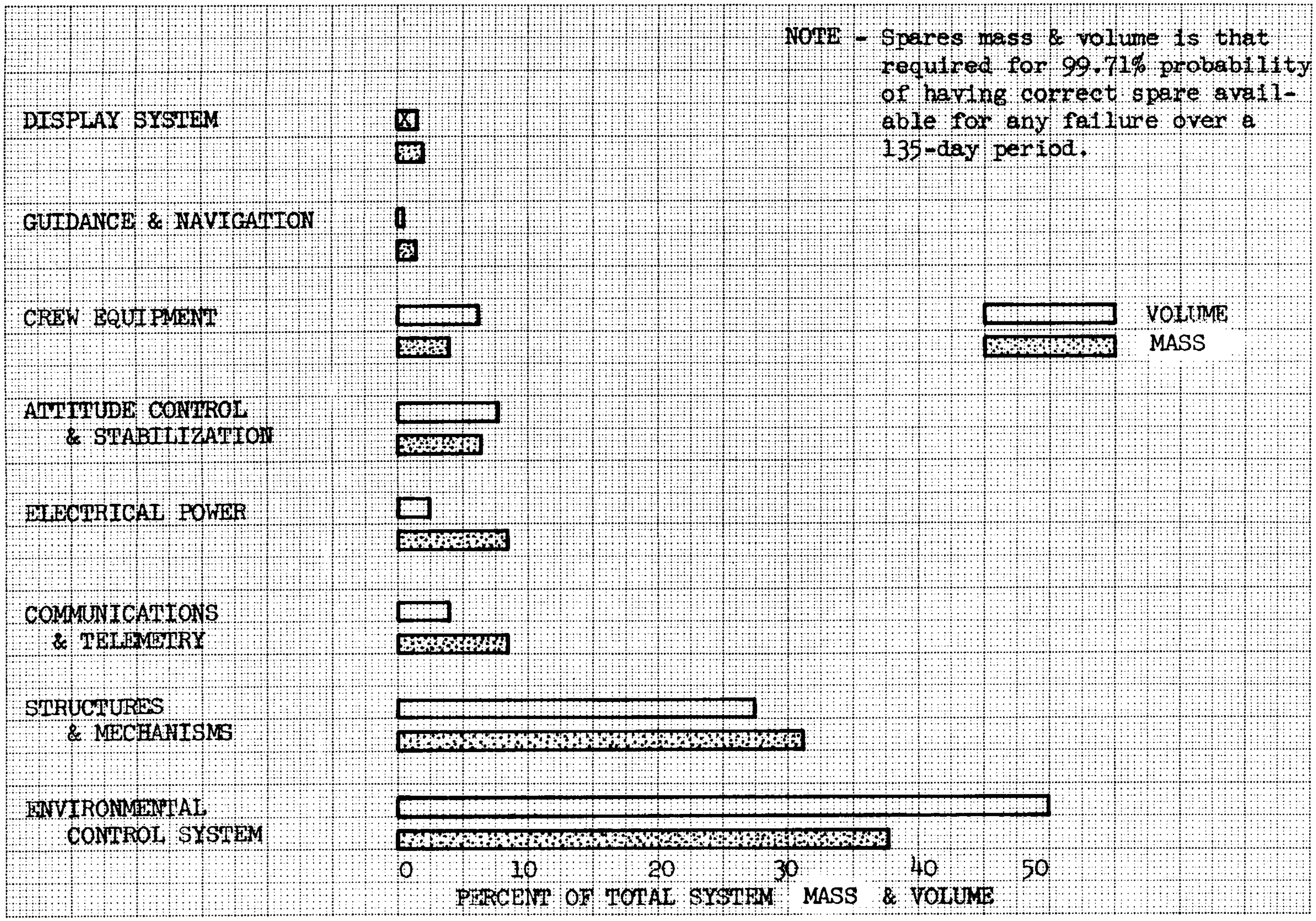


Figure 4.4-4: OLF SYSTEMS SPARES MASS AND VOLUME

OLF Spares Resupply. - After the initial launch of the OLF, it is necessary that the spares used be replenished at the 90-day resupply interval to restore the spares to the original level. The usage of the spares is strictly a function of the component failure rates, except on those items for which a scheduled replacement interval has been established. A simple computer program, written in IBM General Purpose Systems Simulator II (GPSS II) language, was used to simulate the occurrence of failures. The simulation program creates failures randomly within an assumed exponential distribution about the system mean-time-between-failure rate. To obtain a realistic distribution of the data, the computer was run for 100 ninety-day cycles, which would be the equivalent of 25 years. The mass of the spares used to replace the failed components during each 90-day interval was printed out by the computer. This data was plotted in Figure 4.4-7 and is summarized in Figure 4.4-5, which also shows the percentage utilization of initial spares.

FIGURE 4.4-5 OLF SPARES MASS SUMMARY -- 90-DAY RESUPPLY

PREDICTED SPARES USAGE	kg	lb	m^3	ft^3	%
Average	19.5	43	.08	2.8	1.7
Maximum	246	543	1.08	37.8	21.2
Minimum	0.9	2.0	.004	.13	0.08
95% of the time less than	48	110	.204	7.2	4.3

Prior to each resupply mission, an inventory of the spares on board the OLF will be made to determine which spares are required to bring the spares level back to the 135-day supply; these spares will be included as part of the logistic spacecraft payload.

It is expected that the spares mass will approximate the average value of 19.5 kg (43 lbs.) shown on Figure 4.4-5. However, it must be realized that the logistic spacecraft must have the capability of carrying the maximum predicted quantity of 246 kg (543 lbs.) of spares, as there is a finite possibility that this amount will be required eventually. Since the rate of spares usage is a linear function in the area which is being considered for resupply for the OLF, Figure 4.4-8 was plotted to provide an approximation for spares mass usages for resupply intervals at other than 90 days.

Figure 4.4-6 shows the predicted quantity of each type of OLF component which will be used between each 90-day resupply. When this figure is less than one, it is an indication of the fraction of the resupply missions on which one of these components will be carried.

OLF Scheduled Component Replacement Resupply. - In addition to the spares resupply requirements generated by random failures of components, the resupply missions must also carry the components required for scheduled replacements. The only components which have been identified as requiring scheduled replacement are the batteries, which must be replaced once a year. In the event there were any unscheduled replacement of those items during the year, the yearly scheduled replacement schedule for that item would be based on the installation date of the new component. Therefore, the scheduled replacement resupply weights may actually be less than the amount shown. Although these items are required on a yearly basis, it is planned to resupply them over the whole year, rather than impose the complete load on one resupply in each year. Resupply masses for the scheduled replacement components are shown in Figure 4.4-6.

FIGURE 4.4-6 OLF SCHEDULED COMPONENT REPLACEMENT RESUPPLY MASS

ITEM	Quantity Rec'd - Year	Mass Each	Mass Total	Mass Resupply
Battery	4	192	768 (348 kg)	*192(87kg)

* One battery is brought up at each resupply mission.

4.4.4 Integrated OLF Spares Requirements. -

Integrated Initial OLF Spares. - The integrated OLF spares loading includes the spares for the following:

1. OLF proper,
2. Checkout equipment,
3. Apollo logistics spacecraft command module,
4. Orbital support equipment (4 AMUs & 1 RMU),
5. Orbital launch vehicle,
6. Orbital tankers.

The OLF proper spares data was accumulated as described in Paragraph 4.4.3. Spares requirements for the other systems or equipment, except for lgoistic spacecraft, were determined from available failure rates and mass data and fed into the Boeing computerized spares model. Information on the Apollo C/M was not available; therefore, it was necessary to estimate its spares requirements. Since the OLF spacecraft includes an Apollo spacecraft, it was estimated that it would require 25 - 30% of the spares for the total OLV.

The total integrated spares requirements were established based on a probability of 99% of having the correct spare for the total system. This requires that

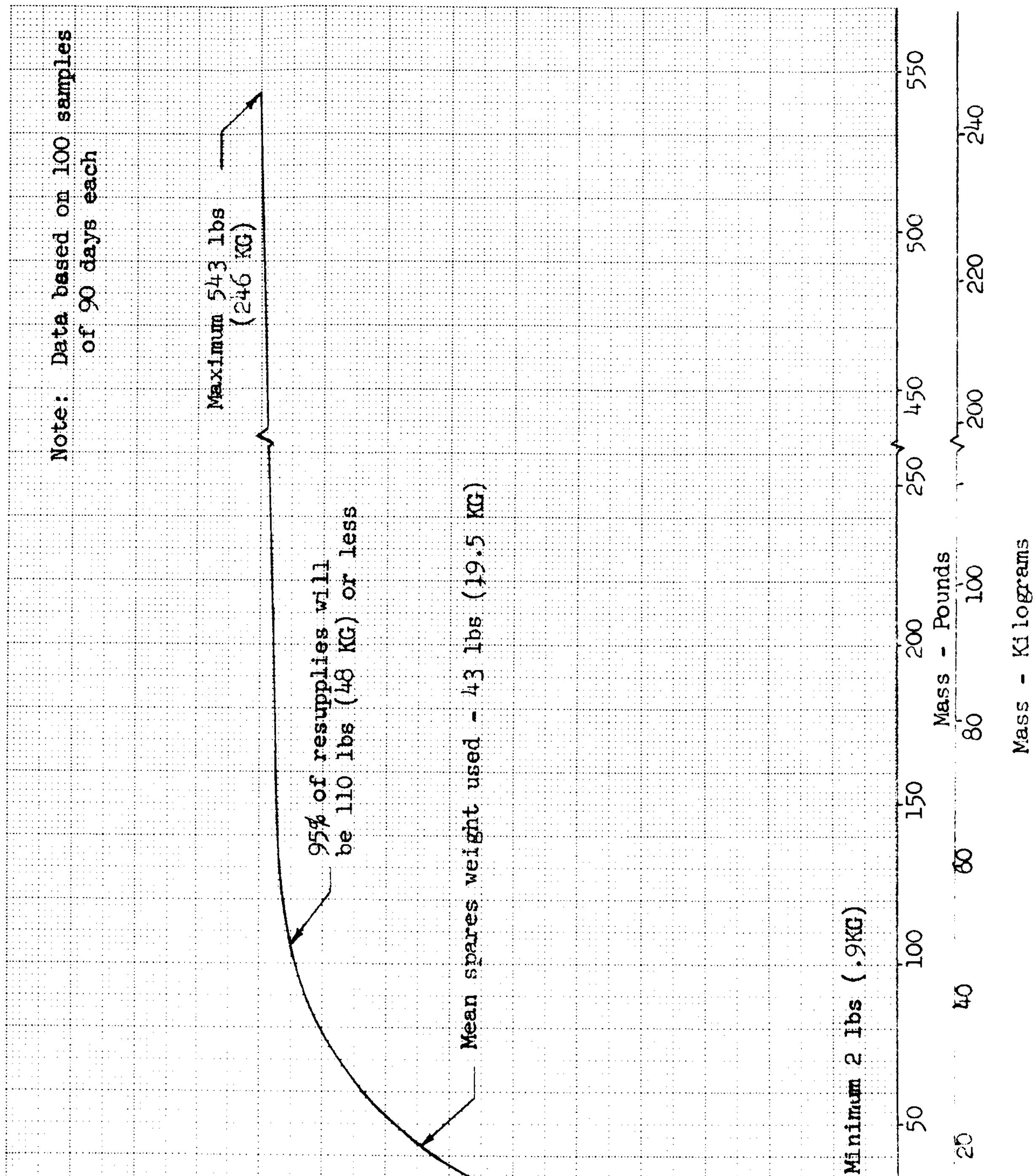


Figure 4.4-7: OLF SPARES MASS – 90 DAY RESUPPLY

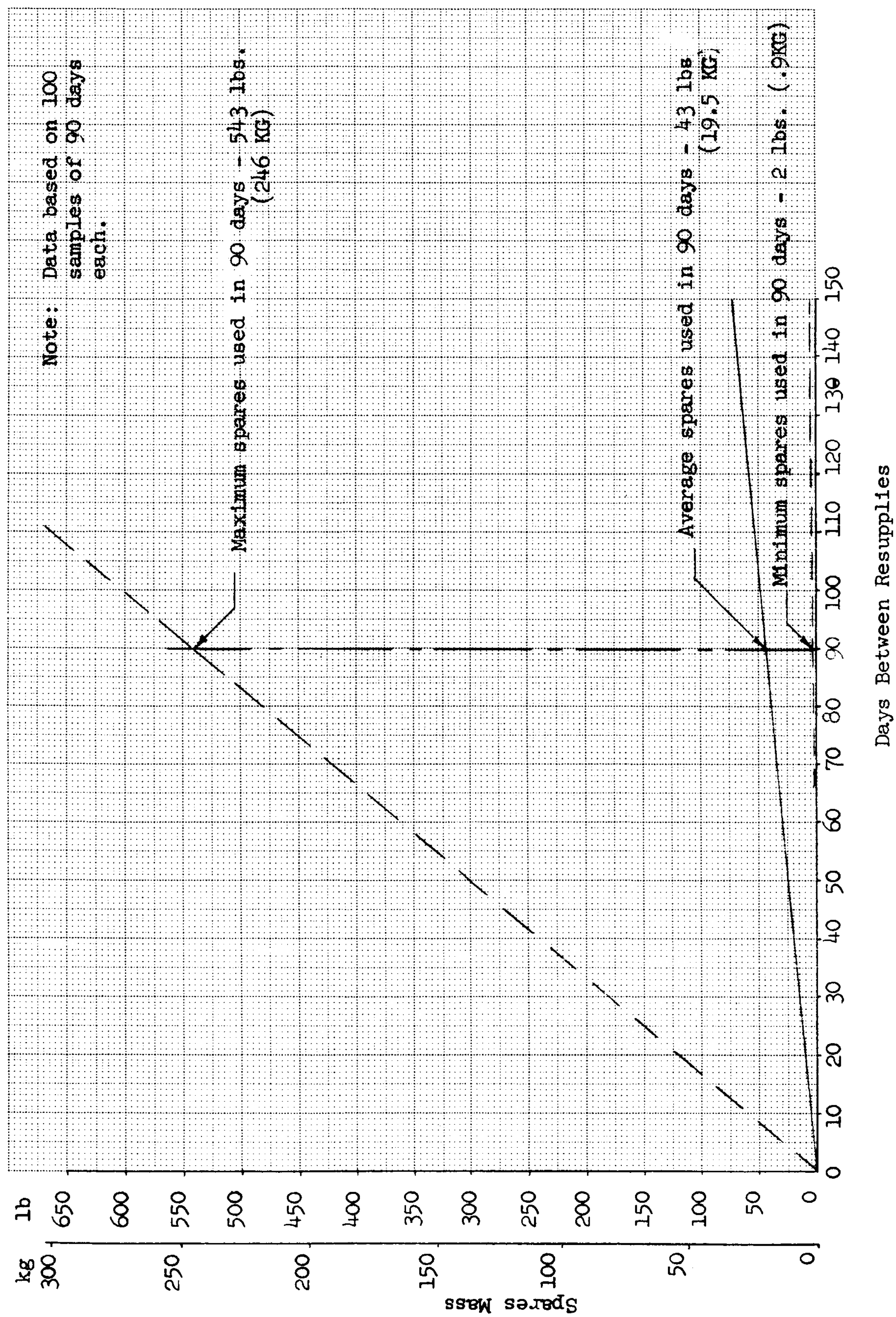


Figure 4.4-8: OLF SPARES USED - 0 TO 150 DAY RESUPPLY

for each of the systems identified above, the probability be something greater than 99%. Therefore, to ensure that the total system probability is optimized by mass, it was necessary to allocate the individual system probabilities to achieve an optimum 99% probability for the total system. The method used to accomplish this is described in Boeing Coordination Sheet Number SS-209, dated 3/23/64, entitled "Maximization of Reliability Subject to a Weight Constraint". Figure 4.4-9 shows the resulting probability allocation and resulting mass for each of the systems.

FIGURE 4.4-9 INTEGRATED OLF INITIAL SPARES MASS - 135 DAYS

INTEGRATED SYSTEM	PROBABILITY OF CORRECT SPARE	kg	lb
OLF	0.99710	1155	2546
Checkout Equipment	0.9993	68	150
Logistic Spacecraft	0.99913	247	545
Orbital Support Equipment	0.9999	199	438
Orbital Launch Vehicle	0.99450	1433	3160
Orbital Tankers	0.99949	415	915
TOTAL	0.99005	3517	7754

Integrated OLF Spares Resupply Requirements. - OLF spares resupply requirements were determined through the use of a computer simulation program as described in Paragraph 4.4.3. This simulation program was not used on the other systems comprising the integrated OLF; however, the spares usage rate would be expected to be about the same as for the OLF. Therefore, using this rate, which assumes the minimum, average, and maximum spares usage rates for 90 days to be .08%, 1.7%, and 21.2% of the initial spares loading for a 99.7% probability of having the correct spare, the integrated spares usage rate was developed, and is reflected in the following.

The low usage rate is a result of the very low failure rates, which were directed for use in this study (see Paragraph 4.4.2).

FIGURE 4.4-10 INTEGRATED OLF SPARES RESUPPLY MASS - 90 DAYS

INTEGRATED SYSTEM	Average		Minimum		Maximum	
	kg	lb	kg	lb	kg	lb
OLF	19.5	43	0.9	2.0	246	543
Checkout Equipment	1.8	4	0.6	1.3	6.4	14
Logistic Spacecraft	11.0	24	3.5	7.7	37	81
Orbital Support Equipment	6.4	14	2.0	4.5	21	47
Orbital Launch Vehicle	84.0	184	27.0	60.0	29	64
Orbital Tanker	18.0	40	6.0	13.0	64	140
TOTAL	140.7	309	40.0	88.5	403.4	889

The predicted average mass for spares resupply of the integrated OLF includes the predicted spares usage due to unscheduled failures of components in the systems and the spares required for OLF scheduled component replacement discussed in Paragraph 4.4.3. These total figures are shown in Figure 4.4-11. Scheduled replacements requirements for systems other than the OLF are not known at this time and, therefore, are not included.

FIGURE 4.4-11 INTEGRATED SPARES REPLACEMENT MASS - 90 DAYS

ITEM	kg	lb
Average integrated spares mass from Fig.4.4-10	140.7	309
OLF scheduled replacement mass from Fig.4.4.-6	87	192
Total 90-day resupply mass	322.7	709

4.4.5 Expendables Requirements. - To support the OLF proper, its crew, and OLO, certain supplies and expendables must be provided and regularly resupplied. Spares are not categorized in this study as expendables as they are treated separately (Paragraph 4.4.3 & 4.4.4). Expendables subject to resupply may be divided into two general categories:

a. OLF proper expendables, which are required to support the OLF and its basic crew and,

b. Mission dependent expendables, which are required to support the Orbital Launch Operations (OLO).

Since the permanent OLF and its associated systems are in continuous operation, their expendables are used at a constant rate; mission dependent expendable consumption varies with the length and type of mission.

Usage Rate of Expendables. - For the purpose of establishing the usage rate of expendables, these have been subdivided into the following categories:

a. Life Support -- This category includes metabolic oxygen, food, water, etc.

b. Propellants -- Includes reaction control system & OSE propellants.

c. Maintenance Tools & Equipment -- Includes small tools & equipment required to maintain the OLF.

d. Crew Support -- Includes personal equipment and miscellaneous supplies and equipment such as kitchenwares, exercise equipment, recreational equipment, etc.

Figure 4.4-12 gives the usage rate of each expendable in terms of men, days, or mission as appropriate. Subsequent figures synthesize the usage within a class.

Life Support Expendables Resupply. - This category includes all expendables required to maintain life in the OLF and includes oxygen and nitrogen requirements, food, medical equipment, and supplies for the environmental control system. Figure 4.4-13 plots the crew size versus the life support expendables required for a period of 90 days, which is the logistic resupply interval. In arriving at the curve, two assumptions were made,which do not appreciably change the resupply masses of life support expendables even though they may be off by a factor of two. The first assumption is that the hangar will be vented into space and repressurized once every ten days, resulting in a total atmosphere loss of 204 kg (450 lbs.) in 90 days; the second is that there will be 30 airlock operations into space every 90 days, which will require a total of 6.2 kg (13.5 lbs.) of replenishment atmosphere.

ITEM	kg	lb
(a) LIFE SUPPORT		
Metabolic Oxygen	0.95	2.1/D/M*
Exp. Bay Atmosphere Leakage		
(1) 7 psia	2.02	4.47/D
(2) 3.5 psia	0.866	1.91
Hangar Atmosphere Leakage		
(1) 7 psia	3.63	8.02/D
(2) 3.5 psia	1.55	3.42/D
Hangar Atmosphere Loss	22.62	50
Hub Atmosphere Leakage	2.29	5.06/D
MORL Atmosphere Leakage (both MORLS)	1.82	4.0/D
Outside Airlock Losses	0.204	0.45/
Charcoal	0.0102	0.0225/D/M
Complexing Agent	0.0134	0.0291/D/M
Wick	0.017	0.0375/D/M
Food	0.753	1.66/D/M
Medical/Dental	0.022	0.0486/D/M
Oxygen Regeneration System	0.086	0.19/D/M
(b) PROPELLANTS		
Attitude Control Orientation Maneuver (0.1°/sec) (using tankers OLV and transtage nozzle as required)		
OLF Spin	5.9	13.00
OLF Non-spin	3.6	8.0
* D = Day M = Man		

Figure 4.4-12: USAGE RATE OF EXPENDABLES

ITEM	kg	lb
OLF/OLV Non-spin	6.4	14.2
OLF/OLV & 1 LOX Tanker Non-spin	6.7	14.8
OLF/OLV & 2 LOX Tankers Non-spin	6.5	14.4
OLF/OLV & 3 LOX Tankers Non-spin	8.1	17.8
OLF/OLV & 4 LOX Tankers Non-spin	10.1	24.2
OLF/OLV/S-II & 4 LOX Tankers Non-spin	12.8	28.4
OLF/OLV/S-II Full/4 LOX empty - Non-spin	25.2	55.6
Attitude Control Hold Attitude (Using tanker, OLF and transtage nozzles as required.)		
OLF Spin	0.31	0.69/hr.
OLF Non-spin	0.37	0.81/hr.
OLF/OLV Non-spin	0.48	1.07/hr.
OLF/OLV & 1 LOX Tanker Non-spin	0.52	1.15/hr.
OLF/OLV & 2 LOX Tankers Non-spin	0.63	1.40/hr.
OLF/OLV & 3 LOX Tankers Non-spin	0.85	1.87/hr.
OLF/OLV & 4 LOX Tankers Non-spin	1.18	2.60/hr.
OLF/OLV/S-II & 4 LOX Tankers Non-spin	1.49	3.30/hr.
OLF/OLV/S-II Full/4 LOX Empty Non-spin	3.17	7.00/hr.
Orbit Keeping (30-day interval)		
OLF Spin (stop & start required)	194	429
OLF Non-spin	40.2	89/usage
OLF/OLV Non-spin	56.6	125/usage
OLF/OLV/1 Tanker Non-spin	65.2	144/usage
OLF/OLV/2 Tankers Non-spin	74.2	164/usage
OLF/OLV/3 Tankers Non-spin	82.2	182/usage

Figure 4.4-12: USAGE RATE OF EXPENDABLES (CONTINUED)

ITEM	kg	lb
OLF/OLV/4 Tankers Non-spin	91.0	201/usage
OLF/OLV/S-II 4 Tankers Non-spin	122.5	271/usage
OLF/OLV/S-II Full/4 LOX empty	122.5	271/usage
Separation Maneuver (OLO) (10 fps separation rate)	226	500
OLF Start & Stop Spin	76.9	170/usage
Docking Assist Reserve (10 fps)		
OLF Only	72.3	160/lbs
OLO	340	750/lbs
Orbital Support Equipment		
AMU	12.9	28.6/usage
AMU	13.6	30/usage
(c) MAINTENANCE TOOLS & EQUIPMENT	0.022	0.0486/D/M
(d) CREW SUPPORT		
Personal Equipment	0.182	0.401/D/M
Miscellaneous Supplies & Equip.	0.45	0.1/D/M
(e) OLV GASEOUS & FLUID SUPPLIES		
Propellants	1812	4000/OLO
Helium (Gaseous)	68	150/OLO
Nitrogen (Liquid)	181	400/OLO
LOX	417	917/OLO
Water (15 day emergency)	122	270/OLO

Figure 4.4-12: USAGE RATE OF EXPENDABLES (CONTINUED)

Propellant Usage & Resupply. - Propellants are expended in attitude control, orbit keeping, and for orbital support equipment. In computing the propellant usage, it was assumed that there would be 20 AMU missions and a total of 6 RMU missions in support of an orbital launch. The propellant usage curve, Figure 4.4-14, shows the OLF propellant consumption for the 170 days preceding orbital launch. The "OLF Proper" curve defines propellant mass required to support the OLF alone independent of any mission, and assumes that the OLF will be spun at 4 rpm to create an artificial gravity once every thirty days. In other words, 50% of the time the OLF will be provided with an artificial-g of 0.382. The "OLO Operation" curve shows propellants required to maintain (at zero-g) the OLF orbit and attitude as required and as the OLV, LOX tankers, and logistic spacecraft are added in accordance with the Logistic Mission Profile Chart, Figure 4.5-1. Also shown is the propellant required for continuous spinning of the OLF alone which is less than the OLF proper propellant, since fewer stop/start spins are required.

The gravitational level analysis study showed the desirability of maintaining a certain level of artificial gravity within the OLF. However, an evaluation of the OLF, when docked to the OLV and tankers, showed that it was not practical to maintain the OLF spinning without increasing propellant consumptions by several factors. This, coupled with an uncomfortable "wobble" which would develop and which would greatly inconvenience the crew, has resulted in the elimination of the artificial-g mode from orbital launch operations portion of the OLF mission.

The OLF at initial launch will provide propellant for the entire 170-day OLO period, plus OLF proper propellants for 45 days having only one start/stop spin (i. e., this added quantity is thus the same as for continuous spinning for 45 days).

Maintenance Tools & Equipment Resupply. - A definition of the maintenance tools and equipment required to support the initial launch is contained in Paragraph 4.2. The 90-day resupply requirements vary from approximately 0.9 kg (2 lbs.) to 2.4 kg (5 lbs.),depending on crew size. For the purposes of this study a figure of 2.4 kg (5 lbs.) is used.

Crew Support Resupply . - The initial mass of crew support equipment & expendables is contained in Paragraph 5.4.6. The 90-day resupply requirements vary in direct proportion to the crew, and are plotted in terms of mass vs. crew size in Figure 4.4-15.

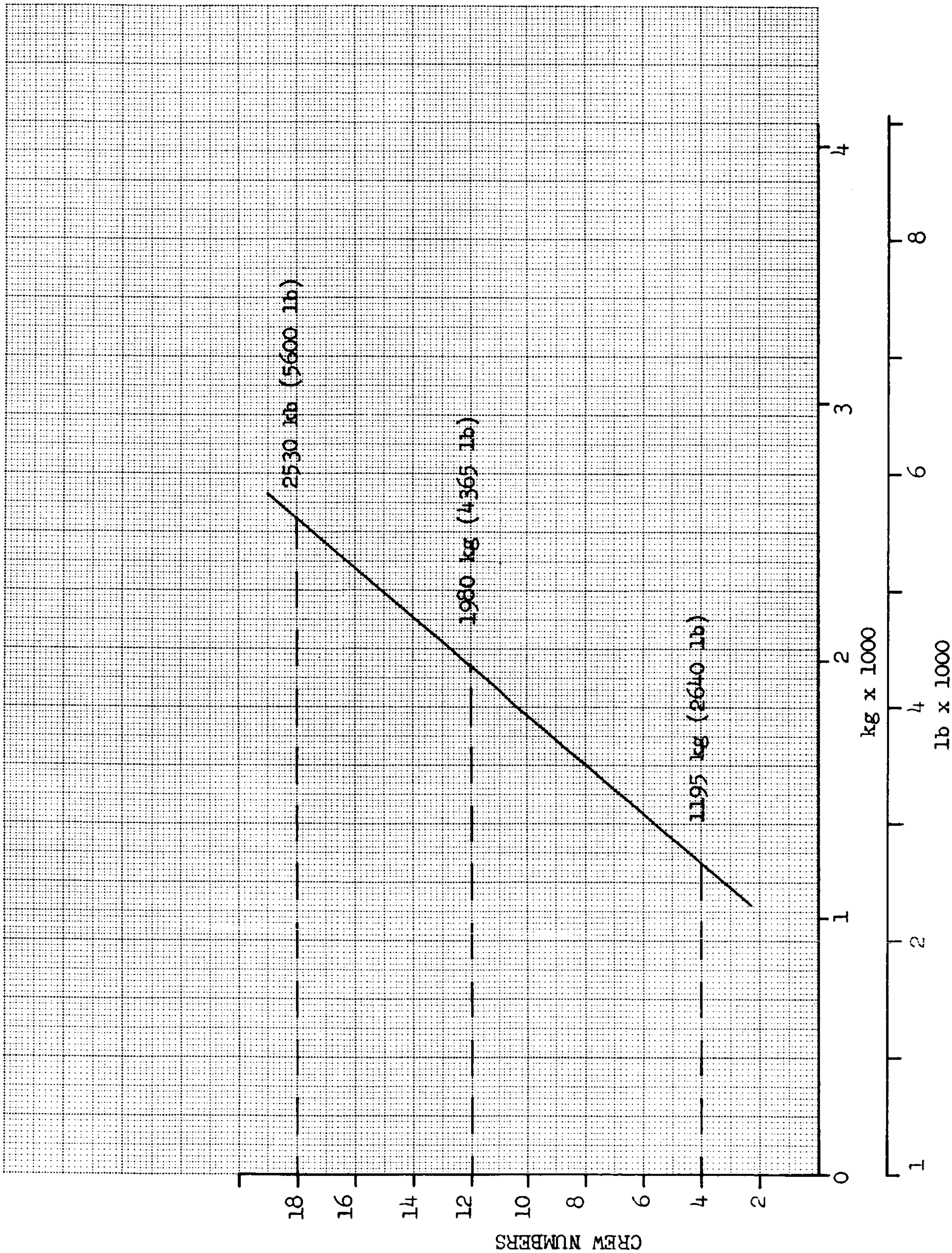


Figure 4. 4-13: 90 DAY LIFE AND CREW SUPPORT RESUPPLY

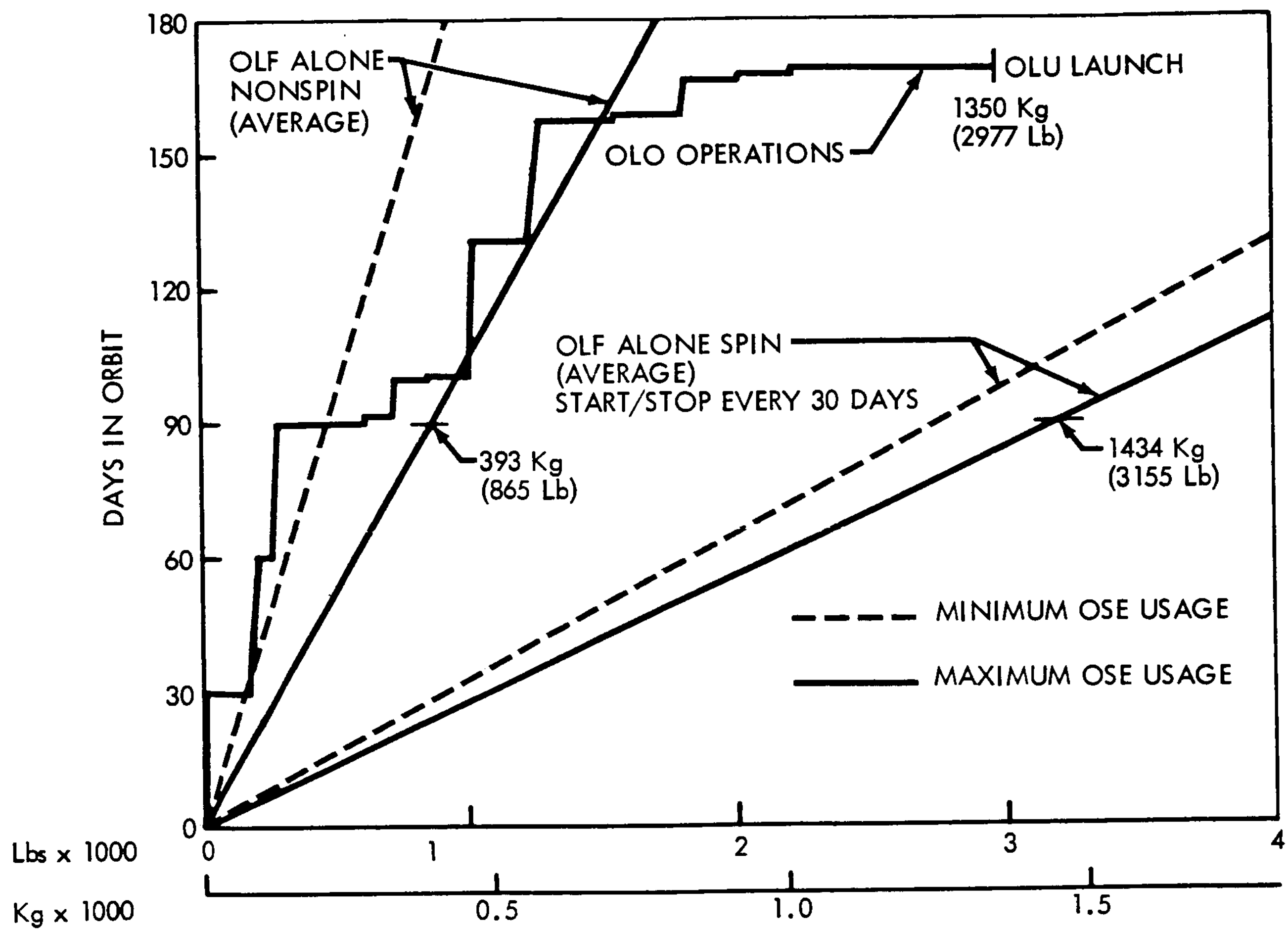
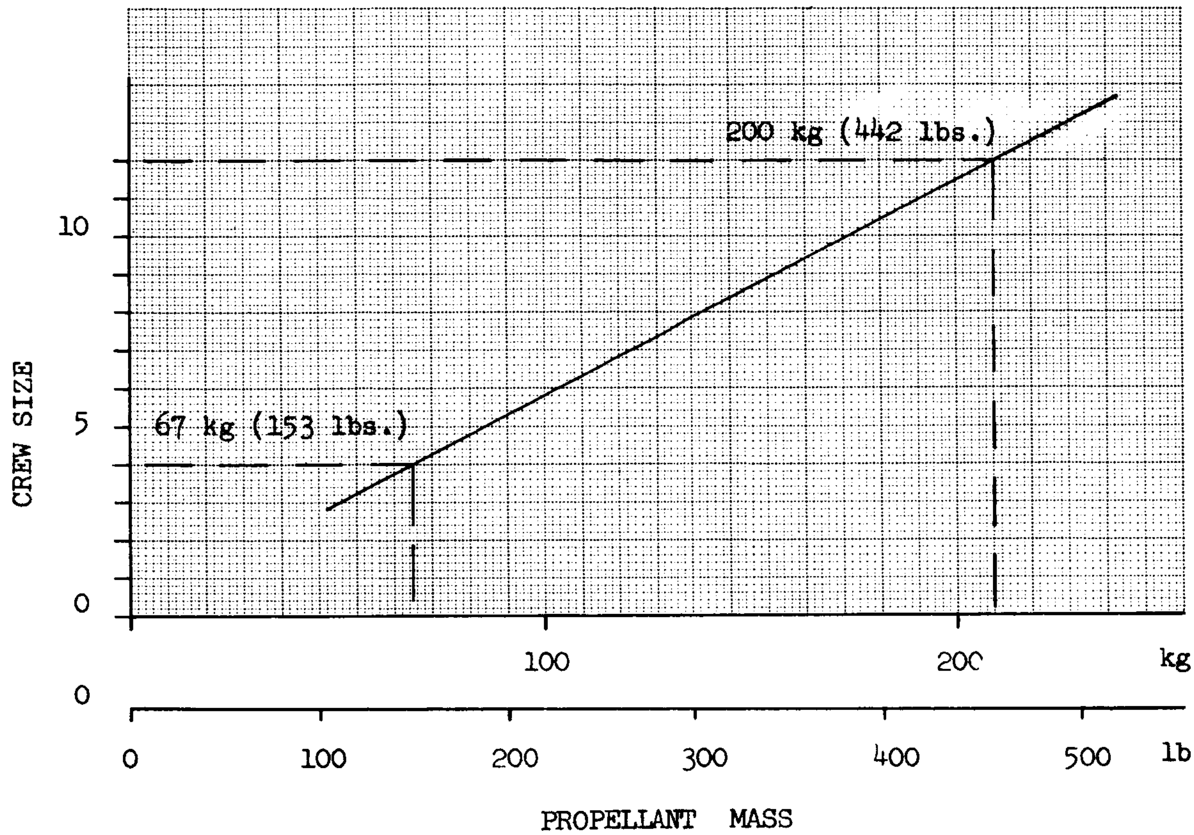


Figure 4.4-14: PROPELLANT USAGE COMPARISON

FIGURE 4.4-15 CREW SUPPORT RESUPPLY MASS - 90 DAYS



ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
	ATMOSPHERE SUPPLY SYSTEM			
	O_2 Tank Pkg. Subcritical			
1	Tank, subcritical O_2	10	0	0
2	Heater	10	0	.0
3	Switch, pressure	10	3	.02
4	HX, Phase control	10	0	0
5	Coupling, fill	10	1	0
6	Coupling (2)	20	1	0
7	Valve, shutoff, solenoid	10	3	.03
8	Valve, relief	10	2	0
	N_2 Tank Pkg. subcritical			
9	Tank, subcritical N_2	2	0	0
10	Heater	2	0	0
11	Switch, pressure	2	2	.03
12	HX, Phase control	2	0	0
13	Disconnect	2	1	0
14	Coupling, fill	2	1	0
15	Coupling	4	1	0
16	Valve, shutoff, solenoid	6	3	.01
17	Valve, relief	6	1	0
	O_2 Pkg. gaseous			
18	Tank, GO_2	4	0	0
19	Coupling	4	1	0
20	Valve, shutoff, solenoid	4	2	.03
	PLSS Supply Pkg.			
21	Tank, GO_2	3	0	0
22	Coupling	3	0	0
23	Valve, shutoff, solenoid	3	2	0
	N_2 Pkg. Gaseous			
24	Tank, GN_2	4	0	0
25	Coupling	4	1	0
26	Valve, shutoff, solenoid	4	2	.04
	Miscellaneous			
27	Valve, off-on, solenoid	12	3	.04
28	Valve, check	4	2	.01

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
29	HX, N_2	2	1	0
30	HX, O_2	2	1	0
31	Reducer, pressure	8	3	.05
32	Sensor, pressure	4	2	.02
33	Valve, dump	4	1	0
34	Valve, shutoff, solenoid	5	2	.08
35	Valve, refull	14	1	0
36	Disconnect, PLSS	5	1	0
37	Regulator, pressure	12	3	.04
38	Valve, shutoff, manual	4	1	.01
39	Flowmeter	4	2	.02
40	Valve, shutoff manual	16	1	0
41	Regulator, pressure	32	4	.10
42	Face Mask	32	5	.13
43	Valve, airlock dump	8	1	0
44	Sensor, O_2 Partial pressure	9	3	.06
45	Connector, suit	36	1	0
46	Valve, relief, absolute	4	2	.01
47	Valve, diverter manual	4	1	0
48	Valve, temp control	2	2	0
49	Valve, shutoff, manual	19	1	0
369	Valve, damper, manual	2	1	0
370	Fan, diffuser 780 cfm	4	2	.03
371	Fan, 650 cfm	4	2	.03
372	Valve, check	4	1	0
	ATMOSPHERE PURIFICATION SYSTEM			
	CO_2 Removal Pkg.			
50	Canister, silica Gel (2)	8	1	.01
51	Canister, zeolite (2)	8	1	0
52	Valve, diverter (2)	8	1	0
53	Sensor, relative humidity	4	2	.02
54	Valve, diverter (dual)	4	1	0
55	Valve, diverter (dual)	4	1	.01
56	Valve, diverter (dual)	4	1	0
57	Valve, diverter	4	1	.01
58	Timer	4	3	.10
59	Pump, vacuum	4	2	.02
60	Valve, shutoff	4	1	0
	Trace Contaminant - Evap.Pkg.			
61	Pump, water	8	3	.05
62	Valve, diverter (dual)	4	1	0
63	Valve, check	18	3	.01

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
64	Fan, CO_2/suit	16	4	.17
65	Cartridge, chemisorbent	4	1	0
66	Burner, catalytic	4	1	.04
67	Sensor, temp.	6	3	.03
68	Valve, flow control	4	1	0
69	Elbow, water separator	4	1	0
70	Flow meter	4	2	.02
71	HX, Regenerative	4	1	0
72	Valve, check	8	2	0
73	Debris trap & filter	4	2	0
74	Fan, contaminant loop	8	3	.1
75	Flow meter	4	4	.02
76	Canister, charcoal	4	1	0
77	HX, humidity control	4	1	0
78	Switch, pressure	4	2	.02
79	Valve, diverter, manual	4	1	0
80	Valve, check	8	2	0
81	Evaporator	4	1	0
82	Heater	2	1	0
83	Lamp, ultraviolet	4	2	.07
84	Valve, diverter	10	1	0
85	Valve, shutoff	14	1	0
86	Valve, temp. control	6	2	.02
87	Sensor, temp. control	6	3	.03
88	Sensor, O_2 Partial pressure	4	2	0
89	Sensor, CO_2 partial pressure	4	2	0
90	Valve, vent	4	2	.03
91	Valve, relief, absolute	4	2	.04
92	Sensor, temp.	2	2	.01
93	Valve, suit bypass	4	1	0
94	Connector, suit	36	1	0
	Miscellaneous			
95	Gas chromatograph	3	2	.03
96	Mass spectrometer	3	3	.13
	WATER MANAGEMENT SYSTEM			
	Dispenser-Refrigerator Pkg.			
97	Valve, water dispenser	10	1	0
98	Chiller	2	1	0
99	Valve, temp. control	2	2	.01
100	Sensor, temp.	2	2	.0
101	Refrigerator	2	2	0
102	Freezer	2	2	.03

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
	Potable Water Tank Pkg.			
103	Valve, shutoff, manual, water	8	1	0
104	Valve, shutoff, manual (2)	8	1	0
105	Valve, temp. control	16	2	.04
106	Sensor, temp.	8	3	.04
107	Heater, water tank	8	1	0
108	Tank, potable water	8	1	0
109	Disconnect, quick, flex hose (2)	16	1	0
	Pretreatment Pkg.			
110	Valve, shutoff	4	1	0
111	Valve, diverter	2	1	0
112	Valve, shutoff	12	1	0
113	Valve, check	10	3	.07
114	Tank, urine processing	4	1	0
115	Valve, shutoff	16	1	0
116	Disconnect, urine	4	1	0
117	Pump, urinal	4	2	.03
118	Tank, accumulator	4	1	0
119	Pump	4	2	.03
120	Sensor, conductivity	2	2	0
121	Valve, check, manual override	4	1	0
	Waste Management System			
122	Valve, diverter, coolant	4	1	0
123	Valve, shutoff	4	1	0
124	Dryer, waste	4	1	0
125	Valve, relief	4	2	.01
	Laboratory Conditioning System			
126	Debris trap	9	2	0
127	Fan, cabin, bay ventilation	12	3	.08
128	Valve, check	18	2	0
129	HX, cabin cooling	4	1	0
130	Sensor, temp.	9	3	.08
131	Valve, temp. control	9	3	.03
132	Sensor, temp.	9	3	.01
133	Flow meter	9	2	.01
373	Fan, hub, ventilation	10	3	.06
374	HX, hub cooling	5	1	0
375	Heater, hub heating	5	1	0

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7 %	90-DAY SPARES USAGE
376	Heater, bay heating	2	1	0
	Cooling System			
134	Switch, pressure	3	2	0
135	Pump	6	2	0
136	Reservoir	2	1	0
137	Sensor, temp.	3	2	.02
138	Valve, check	9	2	0
139	HX, Regenerative	3	1	0
140	Valve, diverter	8	2	0
141	Valve, bypass	3	1	0
142	Accumulator	6	1	0
143	Valve, shutoff	3	1	0
144	HX, water to coolant	2	1	0
145	Disconnect, quick	6	1	0
146	Radiator (integral with OLF structure)	6	1	0
377	Reservoir	1	1	0
378	HX	1	1	0
	Heating System			
147	HX - Radio isotope	2	0	0
148	Pump	2	2	.02
149	HX	2	1	0
150	Valve, temp. control	2	2	.02
151	Sensor, temp.	2	2	0
152	Reservoir	2	1	0
153	Valve, shutoff	2	1	0
154	Accumulator	2	1	0
	Heat Transport System			
155	Switch, pressure	3	2	.01
156	Valve, check	4	2	0
157	Accumulator	3	1	0
158	Pump, water	6	2	0
159	HX, regenerative	2	1	0
160	Heater	3	1	0
	Pump Down System			
161	Vacuum Pump	3	2	.01
162	HX, intercooler	7	1	0
163	Valve, shutoff, solenoid	12	3	.02
164	Valve, check	5	2	.01

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7 %	90-DAY SPARES USAGE
165	Tank, storage	3	1	0
379	Valve, diverter, dual	1	1	0
380	Pump, vacuum	1	1	0
	Experiment Lab			
166	Burner, catalytic	2	1	0
167	HX, regenerative	2	1	0
168	Canister, charcoal	2	1	0
169	Valve, shutoff, manual	4	1	0
170	Valve, diverter, temp. control	2	2	0
171	Fan, contaminant control	4	2	.02
172	Debris trap and filter	2	1	0
173	Lamp, ultraviolet	2	2	.03
381	Filter, chemisorbent	2	1	0
	Pressurization System			
382	Tank, GO_2, Bays	2	0	0
383	Tank, GO_2, hub, dock	1	0	0
384	Tank, GO2, hub, storeroom	1	0	0
385	Tank, GO2, hub, terminal	1	0	0
386	Tank, GN_2, bays	2	0	0
387	Tank, GN_2, hub, dock	1	0	0
388	Tank, GN_2, hub, storeroom	1	0	0
389	Tank, GN_2, hub terminal	1	0	0
390	Coupling	10	1	0
391	Valve, shutoff, solenoid	10	3	.03
392	Pressure reducer	20	3	.08
	Oxygen Regeneration System			
398	CO_2 Reduction reactor	2	1	.01
399	Stainless Steel carbon filter	4	1	.01
400	Expendable carbon filter	2	1	0
401	Electrolysis unit	2	1	.01
402	Compressor (blower)	2	1	.02
403	Condenser separator	2	1	0
404	Heat exchanger	2	1	0
405	Check valves	8	1	0
406	Diverter valves	6	1	.01
407	Instrumentation & controls	2	1	.01
	Guidance and Navigation System			
175	Two-axis horizon scanner	4	2	.02
176	Inertial rate integrating gyro	12	3	.04

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
177	Inertial rate integrating gyros	12	2	0
178	Rate gyro	6	3	.09
179	Inertial measuring unit (IMU-Apollo)	1	0	.04
180	Apollo sextant and scanning telescope	1	0	0
181	Digital computer	2	0	.0
182	Single axis horizon detector head	4	2	0
183	Single axis horizon detector electronics	2	1	0
	REACTION CONTROL SYSTEM			
	Pressurization System			
184	Fill Disconnect	2	1	0
185	Fill solenoid	4	2	.01
186	Vent solenoid	16	3	.03
187	Burst disc	10	2	0
188	Valve, relief	10	3	.02
189	Filter	4	2	0
190	Valve, solenoid control	8	3	.01
191	Regulator	4	2	0
192	Switch, pressure	2	2	.01
193	Valve, check	8	1	0
194	Valve, isolation, solenoid	16	3	.05
195	Valve, isolation, manual	32	1	.01
196	Valve, purge control solenoid	4	2	.01
197	Valve, relieve, back pressure	4	2	0
198	Disconnect, vent	4	1	0
	Propellant Feed System			
199	Fill disconnect	4	1	0
200	Fill solenoid	4	2	.01
201	Recirculation solenoid	4	2	.02
202	Disconnect, recirculation	4	1	0
203	Disconnect, purge	4	1	0
204	Valve, purge check	8	1	0
205	Valve, feed line check	8	1	0
206	Filter, feed line	8	2	0
207	Valve, isolation, manual	24	1	0
208	Valve, engine purge	32	4	.08
209	Prevalves, engine	64	5	.25

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
210	Leak detector	64	5	.18
	Leak Detection System			
211	Solenoid, leak check	90	6	.27
212	Transducer, pressure	90	6	.32
213	Disconnect	8	1	0
214	Engine, attitude control	24	3	.04
215	Engine, orbit keeping	8	2	.02
216	Tank assembly, propellant	8	0	0
	Control Electronics			
226	Actuator selection logic	6	3	.01
227	Signal conditioning	12	4	.15
228	Signal processing	12	4	.11
229	Pitch-yaw control logic	8	3	.03
231	Valve drive & hard over monitor	64	3	.04
233	Compensation electronics	12	2	.02
234	Orbit keeping & update	2	2	.01
235	Orbit maintenance controller	2	2	0
236	Spin control & logic	2	2	.01
237	Accelerometer	2	1	0
238	Regulated power supply	4	2	0
	Communications & Telemetry System			
239	VHF/FM Transmitter	2	3	.17
240	VHF/FM receiver	2	3	.07
	Unified "S" Band Transceiver			
241	Power amplifier	2	1	.01
242	Premodulation processor	2	1	0
243	Dual transponder	2	1	.10
244	VHF antenna	4	2	.01
245	"S" band antenna	4	2	0
246	VHF multicoupler	2	1	0
247	"S" band multicoupler	2	1	0
248	Intercom master station	2	2	.02
249	Intercom slave station	12	3	.05
250	50 MC EVA transceiver (incl. with backpack)	12	3	.07
251	50 MC whip antenna (incl. with backpack)	12	2	.08

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
252	TV cameras	6	3	.11
253	TV monitors	6	3	.13
	Electrical Power System			
254	Brayton-cycle package	2	1	.02
255	Reverse current relays	4	1	0
256	Battery control logic modules	4	2	.03
257	Inverters	4	1	.02
258	Main DC voltage regulators	4	1	.01
259	Battery charger regulators	4	1	.01
260	Batteries	4	2	.02
261	Battery voltage regulator	4	1	.01
393	Frequency changers	4	1	.02
394	Transformer-Rectifiers	4	1	.01
395	Radiator	2	0	0
396	Coolant motor pump pkg.	4	2	.02
	Displays-Environmental Control System			
262	Warning Lights	70	3	.04
263	Caution Lights	36	3	.03
264	Quantity indicators	28	3	.04
265	Pressure indicators	44	5	.15
266	Flowmeters	14	3	.01
267	Temperature indicators	32	4	.13
268	Humidity indicators	8	3	0
269	Partial pressure indicators	20	4	.07
270	Pump pressure, differential, indicators	10	3	.03
271	Water conductivity meter	2	2	0
272	Trace contaminants meter	2	2	.01
273	Radiation meter	2	2	.03
	Displays - Reaction Control & Stabilization System			
274	Lights	240	5	.08
275	Digital readout indicator	40	3	.08
276	Gimbal angle indicator	6	1	0
277	CMG speed indicator	8	3	.02
278	Pressure indicator propellant	2	2	0
279	Temp. indicator-propellant	2	2	.01
280	Orbital track display	2	3	.03

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
281	Flight director display	2	4	.10
282	Range display	2	2	.02
283	Elevation angle indicator	2	1	0
284	Azimuth angle indicator	2	1	0
285	Signal output meters	8	3	.06
286	Switch-two position	110	1	0
287	Switch-selector	36	2	.01
	Displays - Communications & Telemetry			
288	Lights	24	3	.01
289	Switch - two position	38	1	0
290	Switch - selector	32	2	0
291	Digital readout indicator	8	2	0
292	Voltmeter	2	2	.02
293	Wattmeter	2	2	0
294	TV monitor	2	2	.04
295	Modulation level meter	2	2	.01
296	Clock	2	2	0
	Displays - Electrical Power			
297	Lights	68	3	0
298	Switch - two position	48	1	0
299	Switch - selector	24	1	0
300	Voltmeter	6	3	.01
301	Ammeter	6	3	.01
302	Frequency meter	2	2	.01
303	Digital readout indicator	4	2	0
	Hatch Mechanisms			
304	Latch, 2-way, vacuum	5	1	0
305	Latch, 2-way pressure	5	1	0
306	Latch, 2-way, pressure, quick open	4	1	0
307	Latch, 2-way, vacuum	3	1	0
308	Latch, 2-way vacuum	4	1	0
	Docking Mechanisms			
313	Damper, logistics dock	12	1	.01
314	Clamp, logistics dock	12	2	.03
315	Damper, OLV/Tanker dock	6	1	0
316	Clamp, OLV/Tanker dock	6	1	.01
317	Motor, reversing, logistics	12	2	.01
318	Switch, 3-position (H)	12	1	0

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
319	Drive, clamp, logistics	12	2	.01
320	Drive, clamp, OLV/Tanker	6	1	0
321	Motor, reversing, OLV/Tanker	6	1	0
322	Transducer, limit	12	2	0
	Logistics Vehicle Stowage			
323	Clamp	18	2	.01
324	Lever	18	1	0
352	Motor, reversing	12	1	0
326	Switch, 6-position	6	1	0
	Equipment Transporter			
327	Clamp	6	2	0
328	Cable/pulley	6	1	0
329	Rollers, guide, support	6	1	0
330	Motor	2	1	0
331	Drive, axle, reduction	2	1	0
332	Motor, reversing	6	1	0
333	Cable/drum	6	1	0
334	Brake, clutch	6	1	0
335	Controls, box	6	1	.01
	Antenna Mechanisms			
336	Motor	1	1	0
337	Drive, antenna, radar	1	1	0
	Hangar Door Mechanisms			
338	Motor, reversing	1	1	0
339	Assembly, travel/lock	1	1	0
340	Latches, open/close/lock	6	1	0
341	Rollers, guide, support	2	1	0
342	Drive, chain, sprocket	1	1	0
343	Switch, 3-position	1	1	0
	Centrifuge			
349	Brake, dynamic	1	1	0
350	Brake, positive, lock	2	2	0
351	Clutch, drive	1	3	.01
352	Drive, V-belt	1	3	.12
353	Motor, variable speed	1	2	0
354	Controls	2	2	.01
355	Rollers, guide, support	2	1	.02
356	Adjuster, lab attitude	2	2	0

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

ITEM NO.	NOMENCLATURE	NO. IN OLF	INITIAL SPARES FOR 99.7%	90-DAY SPARES USAGE
357	Adjuster, seat attitude	2	2	.03
358	Accelerometers	2	3	.04
	Structure			
359	Exterior structure (repair)	1	0	0
360	Interior structure (repair)	1	1	0
397	Power conversion loop handling mechanism	2	1	0
	Crew Subsystem Equipment			
361	Lights	100	3	.02
362	Washer-dryer	2	3	.04
363	Vacuum cleaner	2	1	.01
364	Fire extinguisher	12	0	0
365	Exercise machine	2	2	.02
366	Film viewing equipment	2	2	0
367	EVA backpack	12	1	.01
368	Spacesuit assembly	12	2	.01

Figure 4.4-16: OLF INITIAL AND 90 DAY SPARES USAGE (CONTINUED)

4.5 LOGISTICS

The primary objective of the logistic study is to define the provisions, equipment, supplies, and spares required on board the OLF at initial launch, and to define the resupply expendable requirements in a form applicable to the different phases of orbital missions. As the usage rate of expendables depends on the mission, it is therefore, necessary to develop the requirements for each logistic support mission individually. Annual resupply requirements in support of the OLF proper are estimated to be in the range of 8150 kg (18,000 lbs.) per year, requiring the launching of four logistic spacecraft. The logistic system is a major consideration in orbital facilities and equipment design and has a major effect on the cost of operations.

To determine a basis for a logistic plan, a number of guidelines must be established. The following assumptions have been made and serve as guidelines in formulating the logistic plan:

a. Initial launch will provide life support expendables for 135 days for 12 men; that is, 90 days plus 45 days emergency in the event of a logistic resupply mission failure.

b. Initial launch will provide OLF spares for 135 days for same reason as noted above.

c. The logistic spacecraft will be a 6-man Apollo with a 5440 kg (12,000 lbs.) payload capacity.

d. Crew time in space is a nominal 180 days.

e. Initial launch for the initial OLF is assumed to occur 170 days prior to orbital launch. It is recognized, however, that it may vary from -170D to -152D as a last ditch date, and that OLV launch could occur as late as -85D.

f. Sufficient propellant will be carried in the initial launch to last until start of orbital launch, plus a 45-day emergency supply for the OLF.

4.5.1 Logistic Requirements. - For the purposes of this study the logistics will be based on three distinct operational concepts:

4.5.1.1 Initial OLF Logistic Support. - (Fig. 4.5-1)

4.5.1.2 RDT&E Alternate Logistic Support. - (Fig. 4.5-2)

4.5.1.3 Post OLO Logistic Support

The first concept assumes that the OLF and associated equipment have been adequately tested on Earth and that the orbital launch operation commences with the placing of the OLF in orbit, and ends with the departure of the flyby vehicle. (Figure 4.5-1)

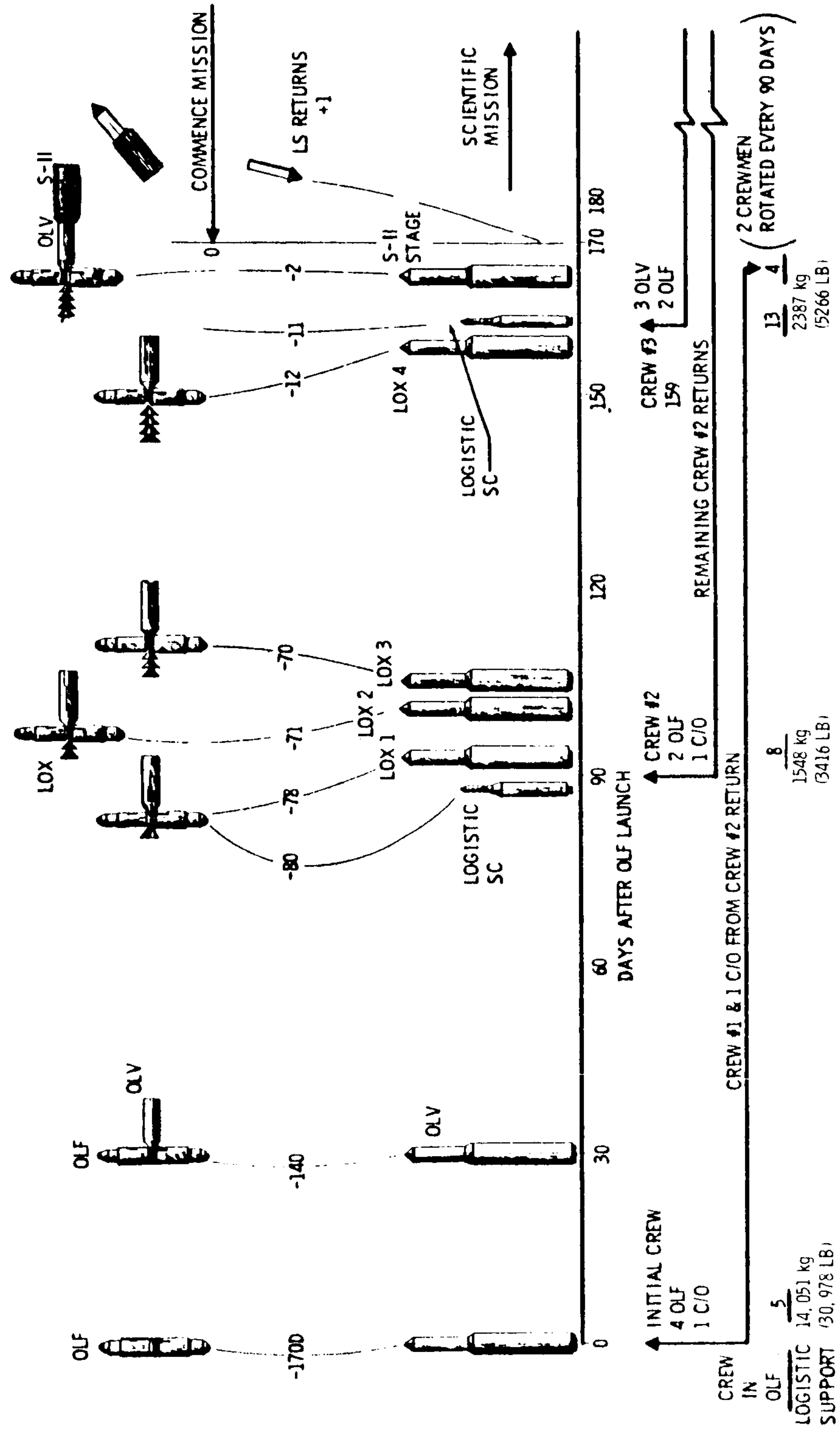


Figure 4.5-1: LOGISTIC SUPPORT PROFILE - INITIAL OLF

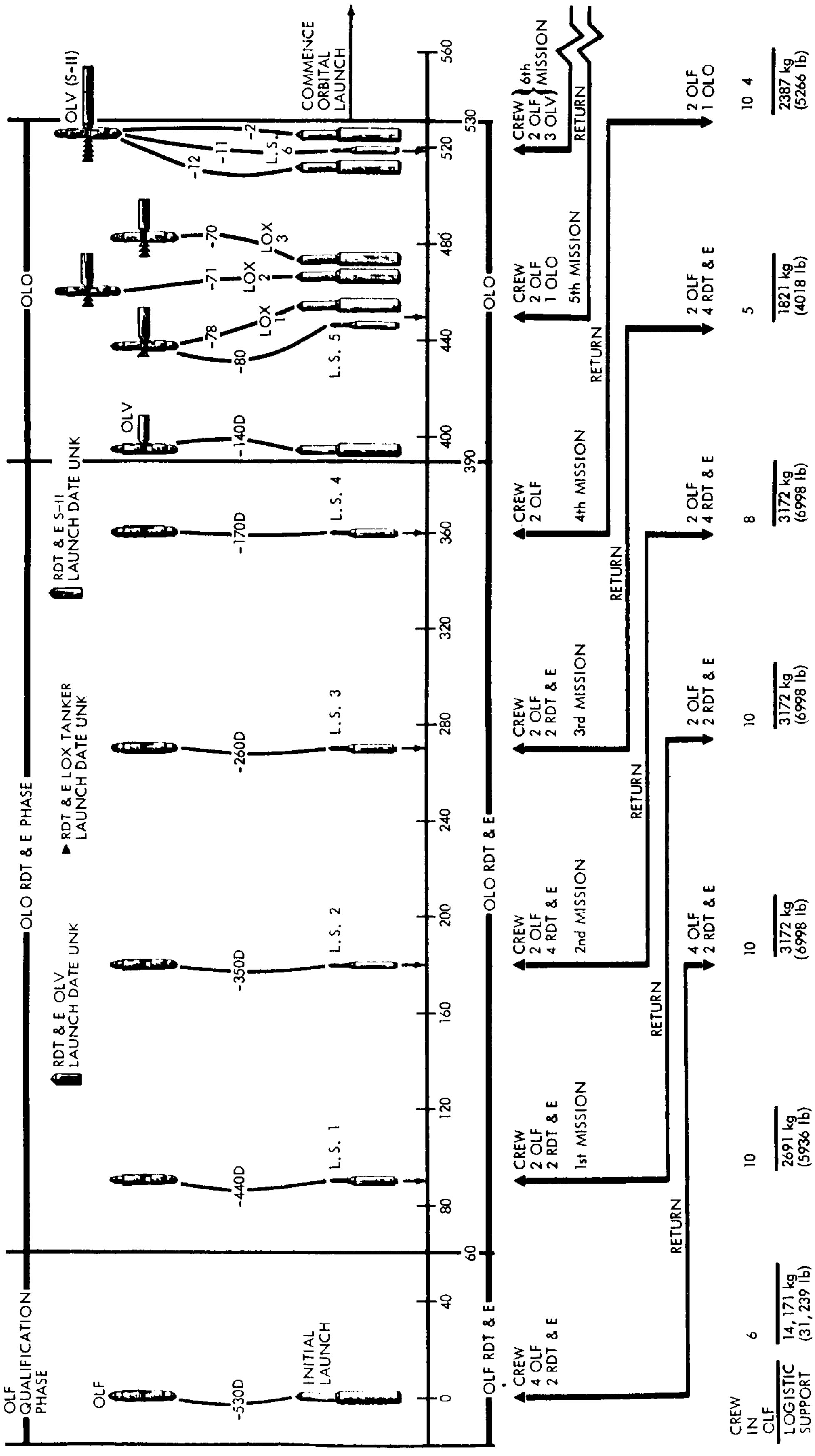


Figure 4.5-2 OLF LOGISTIC SUPPORT PROFILE – QUALIFICATION TESTING

The second concept includes consideration of the OLF & OLO RDT&E activities necessary to bring a new system up to operational status. Included in this concept are three phases; first, the launch of the OLF, which is run through qualification tests; second, an OLO RDT&E phase during which a practice OLV, S-II stage and tankers are launched, rendezvoused and docked; and third, the orbital launch phase itself which starts with the Earth launch of the OLV spacecraft and ends with orbital launch. This concept is graphically portrayed in Figure 4.5-2. Shown in the orbital launch phase are four tankers which are required to support the Mars mission. To support the Venus mission the event schedule would be similar except that only three tankers would be required.

No attempt has been made to define the functions performed under the second concept other than to identify the logistic missions. As the additional test equipment and propellants that are required during OLF qualification testing and OLO RDT&E are unknown, a 20% weight allowance has been added to these in the logistic support requirement.

Post-OLO logistic planning, that is, subsequent to orbital launch, depends on the mission and has not, therefore, been developed in detail. Sufficient parametric data has been provided, however, so that logistic requirements for any mission may be readily determined by appropriate selection of the various data. To assist in this, a post-OLO, typical, resupply chart has been developed, which allows the calculation of mass once the size of the crew has been established (Figure 4.5-11).

4.5.1.1 Initial OLF Logistic Support. - The logistic operations involved in this first concept are divided into the following phases:

a. Initial launch,

b. First logistic mission,

c. Second logistic mission.

Initial Launch Requirements. - As previously noted, the initial launch will contain sufficient spares, life and crew support supplies, and maintenance tools and equipment to support the OLF and a crew of 12 for a period of 135 days and propellant for 170 days. In addition, it will carry certain OLV mission expendables and 45 days OLF proper propellants which include one start and stop spin. It is recognized that the crew initially is limited to 5 men and that in reality expendables for more than 135 days are being supplied. However, the capability to do this exists in terms of both payload and storage, and advantage has been taken of this capability. Figure 4.5-3 provides, in terms of mass, the spares and expendables required for the initial launch to support not only the OLF proper, but the OSE, OLV, and LOX tankers.

ITEM	MASS	
	kg	lbs.
(1) LIFE SUPPORT		
Initial Bay & Hub Pressurization		
O_2	216	476
N_2	190	419
Emergency Repressurization		
O_2	333	734
N_2	293	646
Emergency O_2 (15 days)	171	378
Atmospheric Losses		
O_2	643	1417
N_2	559	1233
PLSS	16	35
Environmental Control Exp.	65	143
Food	1223	2695
Oxygen Regeneration	140	308
Water (15 day emergency)	490	1080
(2) PROPELLANTS		
Initial OLF (170 days, incl. OSE)	1350	2977
OLF Proper (45 days incl. OSE)	488	1075
(3) MAINTENANCE TOOLS & EQUIPMENT	118	261
(4) CREW SUPPORT		
Personnel Provisions	332	731
Misc. Supplies & Equipment	909	2004
(5) SPARES	3517	7754
(6) OLV SUPPLIES		
Propellants	1814	4000
Helium	68	150
Nitrogen	181	400
LOX	417	917
Water (15 day emergency)	122	270
Tools	34	75
Miscellaneous Fluids	363	800
(7) TOTAL	14,051	30,978

Figure 4.5-3: INITIAL LAUNCH LOGISTIC REQUIREMENTS

First Logistic Mission Requirements. - The first logistic mission will be launched approximately 90 days after the initial launch of the OLF. The logistic spacecraft will be required to carry only those expendables and supplies which were consumed during the previous ninety days, plus a crew of three. These supplies will support not only the OLF, but also any other equipment that is being used in the preparation for orbital launch.

Figure 4.5-4 provides, in terms of mass, the supplies required on this mission. It should be remembered that no propellants are required as these were included in the initial launch.

This first mission will end with the logistic vehicle remaining docked to the OLF.

FIGURE 4.5-4 FIRST LOGISTIC MISSION REQUIREMENTS

ITEM	MASS	
	kg	lb
(1) LIFE SUPPORT		
Atmospheric Losses		
O_2	428	945
N_2	375	829
ECS Expendables	18	40
Food	338	747
Medical/Dental	10	22
Oxygen Regeneration	39	85
(2) PROPELLANTS	0	0
(3) MAINTENANCE TOOLS & EQUIPMENT	10	22
(4) CREW SUPPORT	102	225
Personal Equipment		
Misc. Supplies & Equipment		
(5) SPARES	140	309
(6) SCHEDULED COMPONENT REPLACEMENT	87	192
TOTAL	1548	3416

Second Logistic Mission. - The second logistic mission will be launched 69 days after the first mission, that is, eleven days prior to orbital launch. The mission will carry the OLV crew of three, plus two OLF crew members, and will not return until successful initiation of orbital launch. Expendables consumed during the previous 69 days will be replenished, as will sufficient supplies to make up for those consumed during the 11 days prior to orbital launch. This mission will supply sufficient propellants to support the OLF for the 90-day period subsequent to orbital launch. The second half of this logistic mission takes place immediately after successful orbital launch; the original crew of five and one individual from the first mission are returned to Earth in the Apollo logistic spacecraft used in the initial launch. Figure 4.5-5 provides, in terms of mass, the supplies required for the mission.

FIGURE 4.5-5 SECOND LOGISTIC MISSION REQUIREMENTS

ITEM	MASS	
	kg	lb
(1) LIFE SUPPORT		
Atmospheric Losses		
LO_2	428	945
LN_2	375	829
ECS Expendables	28	63
Food	520	1152
Medical Dental	15	34
Oxygen Regeneration	39	85
(2) PROPELLANTS	613	1348
(3) MAINTENANCE TOOLS & EQUIPMENT	15	34
(4) CREW SUPPORT	158	347
Personal Equipment		
Misc. Equip. & Supplies		
(5) SPARES	108	237
(6) SCHEDULED COMPONENT REPLACEMENT	37	192
TOTAL	2387	5266

4.5.1.2 RDT&E Alternate Logistic Support. - Logistic operations involved in this concept start with the initial launch, followed by 90-day resupply missions which take place until orbital launch is accomplished. The requirements for each of these logistics missions are defined in subsequent figures.

Initial Launch Requirements (RDT&E). - Requirements for the initial launch under the RDT&E alternate concept are identical to those under the initial OLF concept; that is, sufficient supplies to maintain the OLF and a crew of 12 for 135 days will be provisioned. As sufficient payload capability exists, propellants to support OLO, even though over a year away, will be included in this launch. The only exception will be that the figure for maintenance tools and equipment will be doubled to compensate for additional equipment, which may be required for OLF qualification testing and OLO RDT&E. Figure 4.5-6 defines initial launch requirements.

FIGURE 4.5-6 RDT&E INITIAL LAUNCH LOGISTIC REQUIREMENTS

ITEM	MASS	
	kg	lb
(1) LIFE SUPPORT		
Initial Bay & Hub Pressurization		
O_2	216	476
N_2	190	419
Emergency Pressurization		
O_2	333	734
N_2	293	646
Emergency O_2 (15 days)	171	378
Atmospheric Losses		
O_2	643	1417
N_2	559	1233
PLSS	16	35
Environmental Control Exp.	65	143
Food	1223	2695
Water (15 day emergency)	490	1080
Oxygen Regeneration	140	308
(2) PROPELLANTS		
Initial OLF (170 days incl. OSE)	1350	2977
OLF Proper (45 days, incl. OSE)	488	1075
OSE		
(3) MAINTENANCE TOOLS & EQUIP.	237	522
(4) CREW SUPPORT		
Personnel Provisions	332	731
Misc. Supplies & Equip.	909	2004

FIGURE 4.5-6 RDT&E INITIAL LAUNCH LOGISTIC REQUIREMENTS - continued

ITEM	MASS	
	kg	lb
(5) SPARES	3517	7754
(6) OLV SUPPLIES		
Propellants	1814	4000
Helium	68	150
Nitrogen	181	400
LOX	417	917
Water	122	270
Tools	34	75
Miscellaneous Fluids	363	800
(7) TOTAL	14,171	31,239

FIGURE 4.5-7 FIRST LOGISTIC MISSION REQUIREMENTS (RDT&E)

ITEM	MASS	
	kg	lb
(1) LIFE SUPPORT		
Atmospheric Losses		
O_2	428	945
N_2	375	829
ECS Expendables	22	48
Food	406	897
Medical/Dental	12	26
Oxygen Regeneration	46	102
(2) PROPELLANTS	613	1348
(3) MAINTENANCE TOOLS & EQUIP.	12	26
(4) CREW SUPPORT	102	225
(5) SPARES	140	309
(6) SCHEDULED COMP. REPLACEMENT	87	192
(7) 20% for RDT&E	531	989
(8) TOTAL	2691	5936

First Logistic Mission Requirements (RDT&E). - The first logistic mission will be launched 90 days after the initial OLF launch. The logistic spacecraft will replenish those supplies and expendables used during the previous 90 days by a crew of 6, plus any spares that may be required. As the exact requirements for support of the RDT&E program have not been developed, a 20% overall factor has been included, which will compensate for unknown equipment, expendables, or spares requirements. Figure 4.5-7 defines the logistic requirements.

Second, Third, & Fourth Logistic Mission Requirements (RDT&E). - The logistic requirements for all of these missions are identical, as the supplies that must be replenished are those consumed by a crew of 10 and other normal OLF operations. A 20% factor has been added to compensate for RDT&E unknowns. Figure 4.5-8 defines the logistic requirements.

FIGURE 4.5-8 2ND, 3RD & 4TH RDT&E LOGISTIC MISSION REQUIREMENTS

ITEM	MASS	
	kg	lb
(1) LIFE SUPPORT		
Atmospheric Losses		
O_2	428	945
N_2	375	829
Expendables	36	79
Food	677	1494
Medical/Dental	20	44
Oxygen Regeneration	77	171
(2) PROPELLANTS	613	1348
(3) MAINTENANCE TOOLS & EQUIP.	20	44
(4) CREW SUPPORT	170	377
(5) SPARES	140	309
(6) SCHEDULED COMP. REPLACEMENT	87	192
(7) 20% for RDT&E	529	1166
(8) TOTAL	3172	6998

Fifth Logistic Mission Requirements (RDT&E). The requirements of the fifth logistic mission are similar to those of the first mission for the initial OLF (Fig. 4.5-4) with the exception of propellants and life support. No RDT&E compensating factor has been given as this mission is in direct support of orbital launch. Figure 4.5-9 defines the mission requirements.

FIGURE 4.5-9 FIFTH RDT&E LOGISTIC MISSION REQUIREMENTS

ITEM	MASS	
	kg	lb
(1) LIFE SUPPORT		
Atmospheric Losses		
O_2	428	945
N_2	375	829
ECS Expendables	18	40
Food	541	1195
Medical/Dental	16	35
Oxygen Regeneration	64	136
(2) PROPELLANTS (OLO propellants in initial launch)	0	0
(3) MAINTENANCE TOOLS & EQUIP.	16	35
(4) CREW SUPPORT	136	302
(5) SPARES	140	309
(6) SCHEDULED COMP. REPLACEMENT	87	192
(7) TOTAL	1821	4018

Sixth Logistic Mission Requirements (RDT&E). - The requirements of the sixth mission are similar to the second logistic mission of the initial OLF (Figure 4.5-5), and takes place 69 days after the fifth logistic mission. Figure 4.5-10 defines the logistic requirements.

FIGURE 4.5-10 SIXTH RDT&E LOGISTIC MISSION REQUIREMENTS

ITEM	MASS kg	MASS lb
(1) LIFE SUPPORT		
Atmospheric Losses		
O_2	428	945
N_2	375	829
ECS Expendables	29	63
Food	520	1152
Medical/Dental	15	34
Oxygen Regeneration	39	85
(2) PROPELLANTS	613	1348
(3) MAINTENANCE, TOOLS & EQUIP.	15	34
(4) CREW SUPPORT	158	347
(5) SPARES	108	237
(6) SCHEDULED COMP. REPLACEMENT	87	192
(7) TOTAL	2387	5266

4.5.1.3 Post-OLO Logistic Requirements. - Subsequent to orbital launch, it will be necessary to resupply the OLF and its basic crew of four every ninety days. As the future role that the OLF will play is not fully defined, it is not possible to determine the supplies which will be required, over and above those basic to the OLF. It is expected that equipment and facilities not now defined will be used, creating a need for spares and expendables not presently envisioned. Figure 4.5-11 shows a typical 90-day OLF logistic resupply in terms of crew size versus mass. The items considered are life and crew support, propellants for attitude control and orbit keeping, and spares for the OLF, checkout equipment, logistic spacecraft, and OSE. No propellants or spares which are mission dependent are considered.

4.5.2 Logistic Plan. - The logistic plan has been developed primarily to support the orbital launch operations. The two approaches to OLO have been developed in parallel; in the first one, the initial OLO capability starts with the OLF launch 170 days prior to orbital launch; the second one, the RDT&E alternate, commences with OLF launch 530 days prior to orbital launch. A logistic plan must, therefore, be developed to sustain both these approaches, and also to sustain the OLF after the initial OLO operation.

To properly support OLO, scheduled launches of the OLF, OLV, LOX tankers, and S-II stage must be accomplished to insure that the orbital launch occurs within the constraints of the orbital launch window. The logistic missions are, therefore, governed by OLO schedules. As the RDT&E logistic requirements are not known, a 20% factor has been added to insure that logistic requirements are met; RDT&E schedules have been made compatible with 90-day resupply missions. This allows the initial OLO logistic requirements to be almost identical in both approaches to OLO.

Figures 4.5-1 and 4.5-2, logistic support profiles for initial OLF and the RDT&E alternate, show the more significant events that take place in support of OLO, and which must be considered in defining the logistic mission.

The requirements that must be met in the various logistic missions, have been defined in Paragraph 4.5.1, and comply with guidelines previously established. As the initial launch has sufficient capability, it is planned that spares and expendables carried will provide an emergency supply of 45 days over and above those required for the 90-day resupply interval; this to support a full crew of 12. Another constraint is that the crew members will not remain in space for more than a nominal 180 days, which dictates that every 90 days, half the crew be rotated. Crew requirements vary with the stage of orbital operations from 5 for initial launch, to 13 crewmen required to support orbital launch.

Logistic Spacecraft. - The logistic spacecraft selected is a six-man Apollo capable of delivering a payload of 5440 kgs (12,000 lbs.) to the OLF. The spacecraft will consist of the command module and a service module. The command module is the habitable portion of the vehicle and contains the crew members at 7 psia, a shirtsleeve atmosphere, and will be used to return astronauts to Earth. The CM is capable of docking at either of the MORLs or to the hub; normally, it will be stowed in the MORLs. Subsequent to docking, transfer of crew members into the OLF will be accomplished in a shirtsleeve environment. The service module will be used to carry all supplies and expendables, liquid or solid, and will be

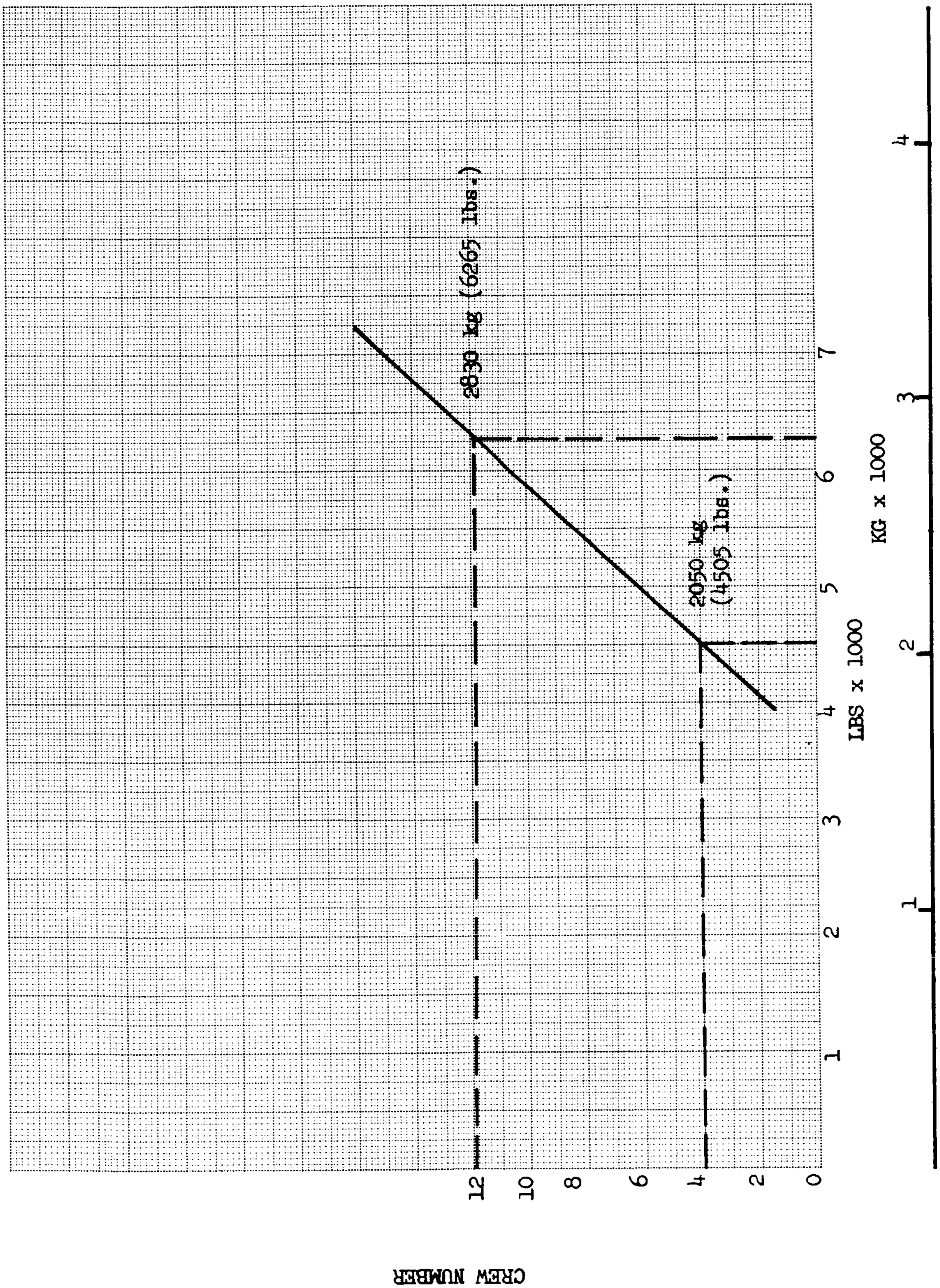


Figure 4.5-11: TYPICAL POST OLO RESUPPLY MASS

used to store trash and refuse. On return missions it will be deorbited over the ocean, thus, assuring disposal of all refuse.

No additional data on the Apollo spacecraft is provided as this is a subject of a separate study.

Logistic Plan for Initial OLO Capability. - The logistic plan for sustaining the entire orbital operations in the Manned Mars Flyby Mission has been developed by analyzing the operations that must occur, pad constraints, crew and supply requirements, and a general overall evaluation of OLO. Figure 4.5-12 summarizes the plan in terms of flight schedules, weight, and crew number.

Post-OLO Logistics Plan. - It is not possible to define a post-OLO logistic plan in absolute terms, as the logistic requirements will vary with the post-OLO mission. The logistic requirements for maintaining the OLF in orbit, independent of any mission, amount to approximately 8150 kbs (18,000 lbs.) per year. Resupply will be accomplished at 90-day intervals, requiring some 2050 kg (4,500 lbs) of spares and expendables and a replacement crew of 2. As the capability exists to supply 5440 kg (12,000 lbs.) and a crew of 6 every 90 days, it is expected that post-OLO missions will consume this capability. In terms of weight and manpower, this means that there is 13,600 kg (30,000 lbs.) per annum mass capability available to support these missions, plus manpower to bring the OLF up to 12 men, 8 more than necessary to maintain the OLF. Figure 4.5-11 shows, in terms of crew members vs. mass, the resupply mass required to support the OLF every 90 days. As this amounts to some 2830 kgs (6,250 lbs.) for a crew of 12, the difference between this figure and the logistic spacecraft resupply capability is what remains to support specific post-OLO missions, i. e., 10,400 kg (23,000 lbs.) per year.

4.5.3 Logistic Technological Problems. - The OLF logistic study has indicated a number of areas where additional study or experience in space will be required to arrive at solutions for problems that arise in fulfilling the logistic requirements. Though many of these problems are common to other space systems, and will be solved prior to OLF launch, all problems must be listed to insure that adequate efforts are exerted toward finding solutions.

The study indicates that those problems associated with rendezvous and the transferring of men and material from a logistic vehicle to the OLF are of primary concern. To date no space rendezvous has ever been completed and no transfer of men or equipment has been accomplished.

The following is a listing of major problems for which solutions must be found to successfully perform logistic missions:

a. Develop a method of transfer of fluids and supplies from the logistic spacecraft to the OLF;

b. Develop rendezvous and docking techniques;

c. Confirm OLF leakage data;

MISSION	CREW SIZE	DAYS TO OLO	LAUNCH VEHICLE	SUPPLY PAYLOAD kg	SUPPLY PAYLOAD lb
OLF Initial Supplies	5	170	S-V	14,051	30,978
OLV Launch Mass	0	140	S-V	112,929	248,968
1st L/M Supplies	3	80	S-IB	1,548	3,416
LOX 1 - Propellant	0	78	S-V	87,642	193,216
LOX 2 - Propellant	0	71	S-V	87,642	193,216
LOX 3 - Propellant	0	70	S-V	87,642	193,216
LOX 4 - Propellant	0	12	S-V	87,642	193,216
2nd L/M Supplies	5	11	S-IB	2,387	5,266
S-II Stage (H_2) Propellant	0	2	S-V	79,113	154,573
TOTAL *				551,596	1,216,065

* Exclusive of OLF, LSC, TANKER & S-II STAGE MASS

To summarize the above requirements:

OLV Propellants - - - - - - - - - - - - - - - - - - - 927,437 lbs.

OLV Mass - 248,968 lbs.

OLV Supplies and expendables including those required to support the OLV - - - - - - - - 39,660 lbs.

1,216,065 lbs.
(551,595 kg)

Figure 4.5-12: INITIAL OLO LOGISTIC MASS

MISSION	CREW SIZE	DAYS TO OLO	LAUNCH VEHICLE	SUPPLY PAYLOAD kg	SUPPLY PAYLOAD lbs
OLF Initial Supplies	6	530	S-V	14,171	31,239
1st L/M Supplies	4	440	S-IB	2,691	5,936
OLV (RDT&E) Mass	0	UNK	S-V	112,932	248,968
2nd L/M Supplies	6	350	S-IB	3,172	6,998
LOX (RDT&E) Propellant	0	UNK	S-V	87,642	193,216
S-II Stage H_2 - RDT&E	0	UNK	S-V	17,528	38,643
3rd L/M Supplies	4	260	S-IB	3,172	6,998
4th L/M Supplies	4	170	S-IB	3,172	6,998
Mission OLV Mass	0	140	S-V	112,932	248,968
5th L/M Supplies	3	80	S-IB	1,821	4,018
LOX 1 Propellants	0	78	S-V	87,642	193,216
LOX 2 Propellant	0	71	S-V	87,642	193,216
LOX 3 Propellant	0	70	S-V	87,642	193,216
LOX 4 Propellant	0	12	S-V	87,643	193,216
6th L/M Supplies	5	11	S-IB	2,387	5,266
S-II Stage (H_2) Propellant	0	2	S-V	70,114	154,573
TOTAL*				782,302	1,723,785

* Exclusive of OLF, LSC, Tanker & S-II Stage Mass.

To summarize the above requirements:

OLV Propellants	1,159,296 lb_m
OLV Mass	497,936
OLF supplies & expendables including those required to support the OLV.	67,453
	1,724,685 lb_m
	(782,300 kg)

Figure 4.5-13: INITIAL RDT&E ALTERNATE LOGISTIC MASS

d. Develop packaging techniques for storage of spares and expendables in a space environment;

e. Develop lightweight containers for storing supplies;

f. Develop a stock level accounting system which will allow a fast determination of spares and expendables so that resupply requirements can be ascertained up to the last minute prior to a logistic mission;

g. Develop storage bins capable of storing supplies in zero and artificial gravity.

h. Develop a method of transferring materials in artificial gravity;

i. Develop a method of transferring materials within the OLF in a zero gravity environment.